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THE LITHOSTRATIGRAPHY AND STRUCTURE OF THE GRAND BRUIT–CINQ CERF AREA (PARTS OF NTS AREAS 110/9 AND 110/16), SOUTHWESTERN NEWFOUNDLAND

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ABSTRACT

Early Paleozoic rocks in the Grand Bruit–Cinq Cerf area constitute part of the Hermitage Flexure in southwestern Newfoundland. Nineteen map units containing volcanic, sedimentary, metamorphic, hypabyssal and plutonic rocks are described. Major fault zones bound three regional belts of rocks, each distinguished by either a unique depositional, intrusive or thermal history.

Inhomogeneous regional deformation is related to the evolution of a vertical shear belt. Simply deformed low-grade rocks and complexly deformed high-grade rocks were probably initially juxtaposed by large-scale overthrusting or underplating. Subsequent dip-slip movements occurred in association with vertical shortening and horizontal extension. Syntectonic intrusions were preferentially emplaced in fault zones that were affected by a relatively large vertical extension. Strike-slip movements were locally important in the late stages of ductile faulting, and developed prior to the flexuring of the structures in the Hermitage system.

INTRODUCTION

Geographic Location, Access and Purpose

The Grand Bruit–Cinq Cerf map area is located near the southwestern coast of Newfoundland some 40 km west of Burgeo and 80 km east of Port-aux-Basques (Figure 1). The village of Grand Bruit is not accessible by road, although it is serviced throughout the year by Marine Atlantic coastal boats. The region is physiographically dominated by the Highlands of Grand Bruit, a geologically controlled, glacially eroded, rocky, barren upland. Access to the coastal exposures and lowlands is by boat. The highlands are most easily surveyed by helicopter-supported fly camps.

This preliminary report documents some of the results of a 1:20,000 scale geological mapping program carried out during the 1986 field season. The purpose of the paper is to comment on the structure and stratigraphy of the region around the Hope Brook Gold Mine. Reports dealing with the economic geology, metamorphic petrology, lithogeochemistry and geochronology of the La Poile Bay–Couteau Bay area are planned over the course of the project.

Regional Setting

The Grand Bruit–Cinq Cerf area is situated within the mobile belt of the Newfoundland Appalachians near the southwestern end of a regional oroflex termed the Hermitage Flexure (Williams *et al.*, 1970; Brown and Colman-Sadd, 1976; Figure 1). The region has been postulated to comprise part of the Appalachian Gander Terrane (after Williams and Hatcher, 1982) or Gander Zone (after Chorlton and Dallmeyer, 1986). Rocks of orthotectonic aspect have a structural, metamorphic and plutonic history similar to the type

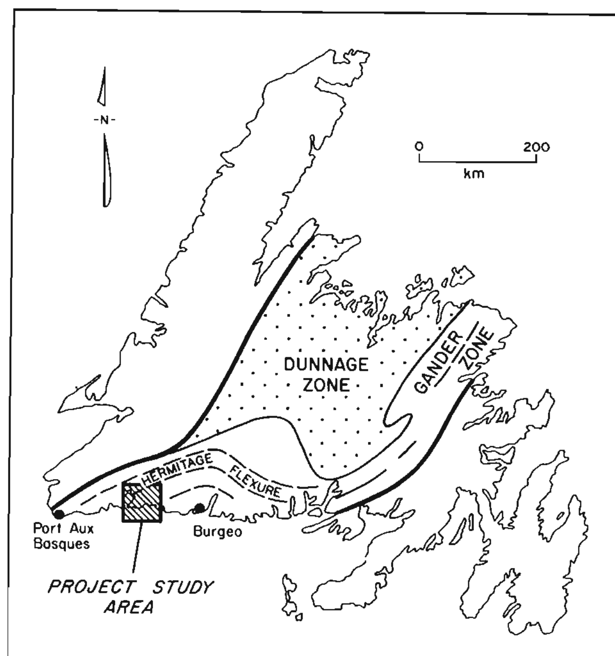


Figure 1: *Location map showing the project study area and the relative positions of the Gander Zone, the Dunnage Zone and the Hermitage Flexure in the Newfoundland Appalachians.*

Gander Zone, whereas those of paratectonic aspect are more closely linked with Ordovician and Silurian strata in the Dunnage Zone of north-central Newfoundland (S. O'Brien *et al.*, 1986). In the map area, the Grand Bruit (Chorlton, 1978), Cinq Cerf (Marten, 1984) and Bay d'Est (Cooper, 1954) faults separate orthotectonic and paratectonic terranes. Fault traces mirror the characteristic Z-shape of the oroflex and, as such, these faults form an integral part of the Hermitage Flexure.

Previous Work

The map area forms part of the La Poile (11O/9) and La Poile River (11O/16) map areas, which were previously mapped by Cooper (1954) on 1:63,360 scale and by Chorlton (1978, 1980) on 1:50,000 scale. These authors established the fundamental rock units and described the regional geological history. Most recently, Swinden (1981, 1984) and McKenzie (1986) have related the gold mineralization near Cinq Cerf (Snelgrove, 1935) to the general geology of the area. Unpublished reports and maps of claim blocks have been prepared by BP−Selco Canada Resources Limited, Mascot Gold Mines Limited (for Dolphin Exploration Limited), Noranda Exploration Company Limited, Buchans Mining Company, Vanna Resources Incorporated, South Coast Resources Limited, MPH Consultants Limited (for Dasher Resources Limited), and OreQuest Consultants Limited (for Powergem Resources Limited, Tanon Resources Limited, Seatac Resources Limited, Dolphin Exploration Limited).

Cooper (1954) believed that the geological development of southwestern Newfoundland could be explained solely by the effects of an Early to Late Devonian Acadian Orogeny. With the exception of some gneisses and granitoids near the northern border of the La Poile River map area, he considered all rocks to be Early Devonian or younger. This conclusion was based on the following premises: 1) that the oldest map unit (Bay du Nord Group) contained fossiliferous Lower to Middle Devonian strata, 2) that a younger metasedimentary and metavolcanic unit (the La Poile Group) unconformably overlay schist and gneiss thought to be younger than the Bay du Nord Group, and 3) that intrusive rock units were emplaced, for the most part, during the folding of the Bay du Nord and La Poile groups, and were best correlated with Devonian plutonic rocks in the New Hampshire Appalachians. Cooper (1954) concluded that the regional structure of the La Poile and La Poile River map areas is dominated by an anticlinorium−synclinorium pair separated by a major dislocation, which he called the Bay d'Est Fault. He further concluded that rocks of the Bay du Nord Group underlie the northwestern part of the area and occupy the core of the anticlinorium, whereas La Poile Group rocks occur to the southeast in the core of the synclinorium. Belts of schist and gneiss of intermediate age are present on the fold limbs.

Chorlton (1978, 1980) redefined the Bay du Nord and La Poile groups. In the Bay du Nord Group she included schistose and gneissose, sedimentary, volcanic and microgranitic rocks that lie southeast of Cooper's Bay du Nord Group and northwest of the Bay d'Est Fault. U−Pb age determinations on zircons from volcanic rocks in the redefined Bay du Nord Group indicated a Middle Ordovician depositional age (Chorlton and Dallmeyer, 1986). Chorlton (1980) reassigned the fossiliferous Lower to Middle Devonian strata to the Billiards Brook Formation, which outcrops in an elongate belt northwest of the Bay du Nord Group. The La Poile Group was redefined to include all greenschist facies rocks between the Bay d'Est and Grand Bruit faults in the La Poile and La Poile River map areas. U−Pb age determinations on zircons from La Poile Group volcanic rocks reported by Chorlton and Dallmeyer (1986) indicate a Middle Ordovician depositional age, and support Chorlton's earlier suggestion (*in* Chorlton and Knight, 1983) that the Bay du Nord and La Poile groups are lateral facies equivalents. Chorlton refuted the notion that rocks in the Cinq Cerf valley in Cooper's Unit 4 unconformably underlie the La Poile Group as originally defined (Table 1). She erected a three-fold subdivision of the redefined La Poile Group, which consisted of two units of intrusive rocks and one unit of stratified rocks. The intrusive rock units were termed the Roti Granite (the lowest exposed part of the group) and the Hawks Nest Pond porphyry (one of the highest exposed parts of the group). The remainder of the La Poile Group was collectively referred to as the Georges Brook Formation. Because the Roti Granite and Hawks Nest Pond porphyry were interpreted as subhorizontal sills emplaced during deposition of the Georges Brook Formation, the extrusive, intrusive and sedimentary rocks were combined in a single group.

Although the redefined Bay du Nord and La Poile groups are metamorphosed to amphibolite and greenschist facies respectively, Chorlton (1980) considered them to share a common depositional and structural history. They were stated to have been deformed initially by thrusting and recumbent folding in the Late Ordovician or Early Silurian, and again by a generally upright deformation during the climactic metamorphism sometime prior to the Late Silurian (Chorlton and Knight, 1983; Chorlton and Dallmeyer, 1986). Major faults of the Hermitage Flexure system (e.g., the Cape Ray and Grand Bruit faults) were thought to have been initiated at the end of this deformation in the Late Silurian or Early Devonian. Subsequent deformation in the Late Devonian to Early Carboniferous affected the Billiards Brook Formation as well as the partly retrogressed middle Paleozoic basement. Oblique thrust movements on the Bay d'Est Fault were reckoned to have occurred at this time.

Swinden (1981, 1984) and McKenzie (1986) accepted the idea that the La Poile and Bay du Nord groups were temporal equivalents. Swinden (1981) suggested that these groups were proximal volcanic facies of the Baie d'Espoir Group to the east, and regionally comparable with the Early to Middle Ordovician Dunnage Zone island-arc, volcano-sedimentary successions to the north (after Swinden and Thorpe, 1984). McKenzie (1986) cautioned, however, that they were probably deposited in different environments upon different types of crust. Both authors excluded the Silurian Hawks Nest Pond porphyry (Chorlton and Dallmeyer, 1986) from the La Poile Group, which they redefined, yet again, as comprising the Roti Granite and the Georges Brook Formation. Swinden and McKenzie both pointed to the importance of Roti Granite sills as either a heat or fluid source for epithermal gold mineralization near Cinq Cerf, and related the alteration and mineralization to late magmatic events associated with La Poile Group volcanism.

LITHOSTRATIGRAPHY

General Statement

The Grand Bruit−Cinq Cerf map area is underlain by a variety of volcanic, sedimentary, hypabyssal, plutonic and

Table 1: Table of formations

Age	Rock Type	Unit	Lithology	Nomenclature	
				Cooper 1954	Chorlton 1978/1980
Lower Devonian	Intrusive Rocks	19	Pink equigranular granite (intrusive into 2, 6, 7, 9, 12, 14, 16, 17, 18)	Chetwynd Granite	
Siluro-Devonian Or Earlier			*Intrusive contact–end of ductile deformation*		
		18	Feldspar-porphyritic biotite granite containing abundant pegmatite sheets		Otter Point Granite
			Intrusive contact		
		17	Equigranular biotite–hornblende granodiorite containing cognate xenoliths (intrusive into 1, 2, 13; tectonic contact with 6 and 14)		Cinq Cerf Complex
			Not in contact		
		16	Fine grained granite porphyry containing green altered feldspar (intrusive into 4, 6, 7, 9, 10, 11, 12; tectonic contact with 3)	La Poile Porphyry	Hawks Nest Pond Porphyry
			Not in contact		
		15	Gabbro, diorite, intrusion breccia (intrusive into 13)		Ernie Pond Gabbro
			Not in contact		
		14	Leucocratic microgranite and granitic porphyries; locally contains abundant screens of country rock (intrusive into 2, 6; tectonic contact with 1, 17)	Roti Granite	
			Intrusive or gradational contact		
		13	Coarse grained granodiorite containing blue quartz (intrusive into 1, 2)	Roti Granite	
			NOT IN CONTACT		
Silurian, Ordovician Or Earlier	Stratified Rocks	12	Massive and flow-banded rhyolite and rhyolite breccia (tectonic contact with 3)	new unit	
			Conformable contact		
		11	Felsic lithic-crystal tuff (tectonic contact with 3)	new unit	
			Not in contact		
		10	Welded tuff, felsic tuff–agglomerate, argillite, sandstone and conglomerate (conformable with 6, 8)	new unit	
			Conformable contact		
		9	Grit and wacke interbedded with minor argillite (conformable with 7)	new unit	
			Conformable contact		
		8	Flow-banded and massive rhyolite (conformable with 6)	new unit	
			Not in contact		
		7	Polymictic boulder conglomerate and interbedded minor sandstone	basal La Poile Group	
			Conformable contact		
		6	Sandstone and argillite, minor felsic tuff and conglomerate	pre-La Poile Group	lower La Poile Group
			Conformable contact		
		5	Basic tuff and agglomerate	new unit	
			Not in contact		
		4	Undivided sedimentary and volcanic rocks	new unit	
			TECTONIC CONTACT		
Ordovician(?) Or Earlier	Schist	3	Metaconglomerate, psammitic and semipelitic schist; abundant screens of microgranite; minor metavolcanic rocks		Bay du Nord Group
			Not in contact		
		2	Semipelitic and pelitic schist; (2a) metaconglomerate	pre-La Poile Group	
			NOT IN CONTACT		
Ordovician(?) Or Earlier	Gneiss, Schist	1	Paragneiss and schist, amphibolite gneiss, metagabbro		Cinq Cerf Complex

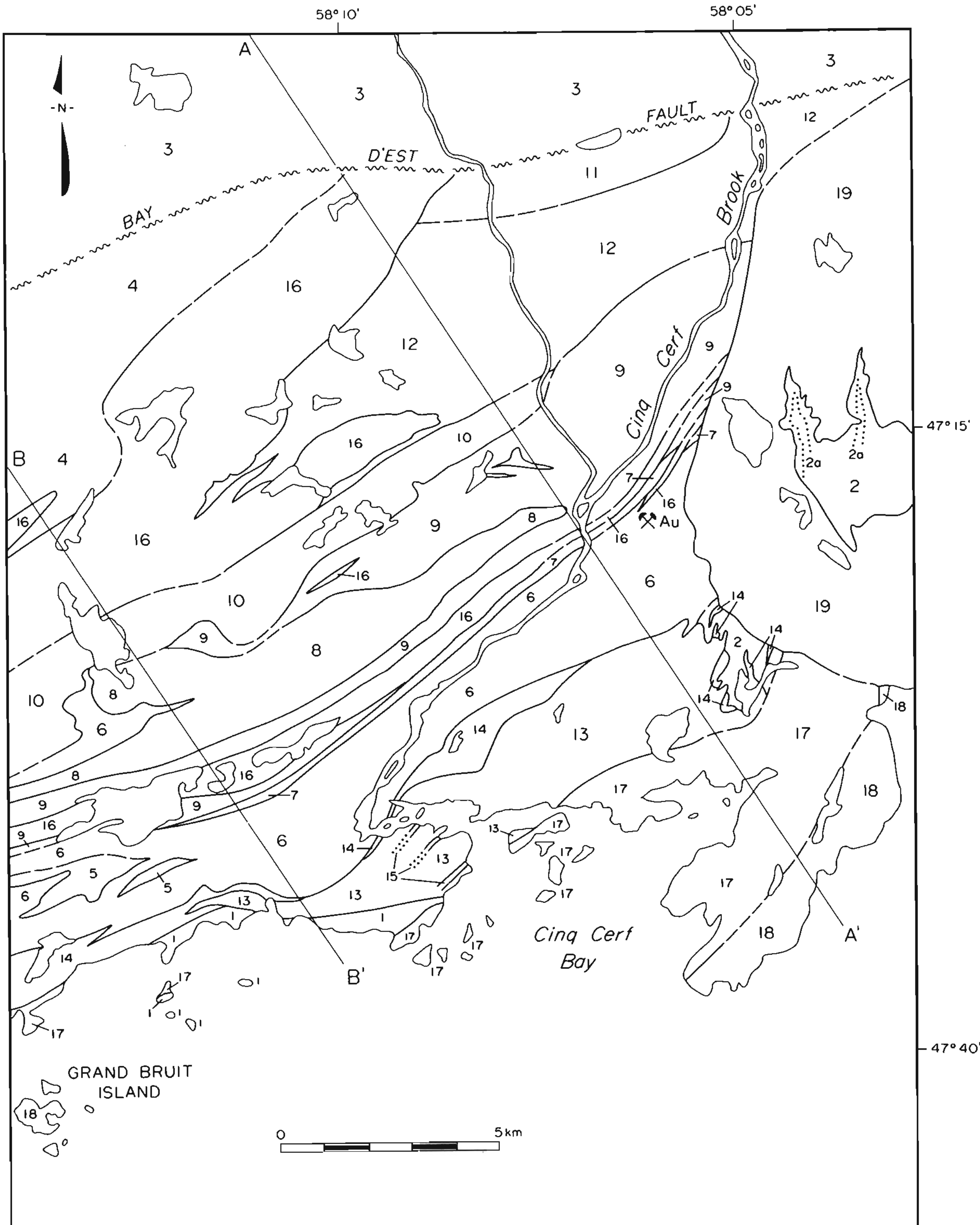


Figure 2: *Geological map of the Grand Bruit–Cinq Cerf area, southwestern Newfoundland. Map unit numbers do not reflect the stratigraphical order. The occurrence of a particular map unit in more than one part of the map area does not necessarily imply structural repetition. The location of the Hope Brook Gold Mine is indicated.*

LEGEND *(Figure 2)*

19 *Pink equigranular granite*

18 *Porphyritic, biotite granite containing abundant pegmatite sheets*

17 *Equigranular biotite–hornblende granodiorite containing cognate xenoliths*

16 *Fine grained granite porphyry containing green altered feldspar*

15 *Gabbro, diorite, intrusion breccia*

14 *Leucocratic microgranite and granite porphyries; locally contains abundant screens of country rock*

13 *Coarse grained granodiorite containing blue quartz*

12 *Massive and flow-banded, pink and cream, rhyolite and rhyolite breccia*

11 *Felsic lithic-crystal tuff*

10 *Welded tuff, felsic tuff–agglomerate, argillite, sandstone and conglomerate*

9 *Grit and wacke interbedded with minor argillite*

8 *Flow-banded and massive rhyolite*

7 *Polymictic boulder conglomerate and interbedded minor sandstone*

6 *Sandstone and argillite, minor felsic tuff and conglomerate*

5 *Basic tuff and agglomerate*

4 *Undivided sedimentary and volcanic rocks*

3 *Metaconglomerate, psammitic and semipelitic schist; abundant screens of microgranite*

2 *Semipelitic and pelitic schist; 2a, metaconglomerate*

1 *Paragneiss, amphibolite gneiss, metagabbro*

metamorphic rocks (Units 1-19, Figure 2, Table 1), most of which are probably Early Paleozoic. They are distributed in three belts lying parallel to the regional tectonic grain (Figure 3). From northwest to southeast, these are: 1) a northwestern belt of metamorphic rocks, 2) a central belt of low-grade stratified rocks, and 3) a southeastern belt of intrusive rocks and high-grade inclusions. Major fault zones separate the three belts.

The northwestern belt underlies the area north of the Bay d'Est fault zone and is chiefly made up of complexly deformed, amphibolite facies metasedimentary and metavolcanic rocks collectively grouped as Unit 3. Greenschist facies, volcanic and sedimentary strata constituting the central belt occur within and northwest of the Cinq Cerf fault zone. Most of Units 4, 5, 6, 7, 8, 9, 10, 11 and 12 are relatively simply deformed. With the exception of Unit 5, the above map units are all crosscut by Unit 16, the sole intrusive unit in the central belt. The southeastern belt is largely composed of intrusive rocks (Units 13, 14, 15, 17 and 18) that occupy the Grand Bruit fault zone. These units are separated, in places, by map-scale septae of metamorphic rocks (Units 1 and 2). Mafic dikes occur in swarms near the boundary between the southeastern and central belts. Unit 19, the only posttectonic intrusion in the map area, is in contact with most map units southeast of the Bay d'Est fault zone. Low-grade rocks and high-grade rocks are either in tectonic contact or they are separated by intrusions (Table 1).

Identification and Nomenclature of Map Units

Seven of the nineteen units mapped during the 1986 field season are newly defined (Figure 2, Table 1). The remaining twelve units were originally mapped by Cooper (1954), although he referred to only seven of these by name. Chorlton (1978, 1980) named and/or redefined seven of Cooper's (1954)

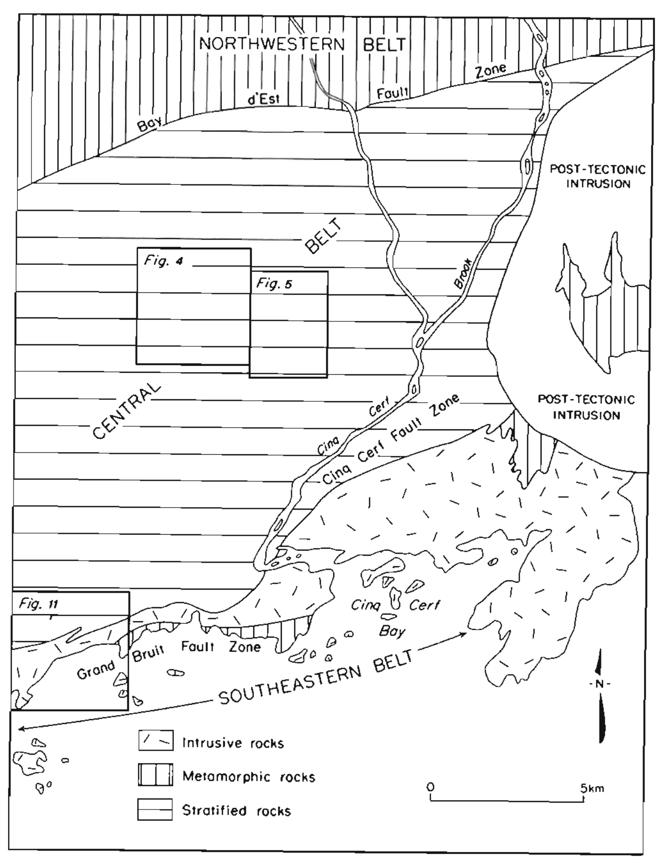


Figure 3: *The disposition of the northwestern belt of metamorphic rocks, the central belt of stratified rocks and the southeastern belt of intrusive rocks (with metamorphic inclusions). Note insets showing the positions of Figures 4, 5 and 11.*

map units. Table 1 shows the correlation between previous nomenclature and present numerical designation. The writer has not named or formally defined any of the nineteen map units in this preliminary report because 1) the presence and form of these units in the La Poile Bay area is unknown (i.e., their regional mappability is not proven), and 2) the stratigraphical order and significance of all units are yet to be established.

Description of Map Units

Gneiss and schist (Unit 1). Unit 1 occurs as a large (about 5 km²) inclusion in the southeastern belt of intrusive rocks (Figure 3), and is well exposed along the coast and on islands west of Cinq Cerf Bay (Figure 2). It consists of well banded, psammitic and amphibolitic gneiss and schist containing distinctive pods of epidote-rich material and calc-silicates. Dikes and bosses of amphibolitized gabbro are locally foliated and cross the gneissic foliation in the banded rocks. The gabbro and gneiss are present as xenoliths in strongly foliated granitoid screens associated with pegmatites and zones of agmatitic migmatite. All of the above rocks have been metamorphosed in the amphibolite facies and are included in Unit 1.

Unit 1 is everywhere in contact with intrusive rocks. To the southeast, undeformed parts of Unit 17 granodiorite post-tectonically intrude most of the foliated rocks grouped in Unit 1. To the northwest, Unit 13 granodiorite intrudes the banding in Unit 1 gneiss and the layering in mylonite derived in part from Unit 1. Mylonitized porphyries (Unit 14?) are present along the northwestern border of the unit.

The amphibolite gneiss and gabbro are similar to mafic meta-igneous rocks in the Burgeo (11P) map area described by S. O'Brien *et al.* (1986) as predating the Bay du Nord Group, and also to the mafic–ultramafic inclusions in the Central Gneiss Terrane of the southern Long Range Mountains (van Berkel *et al.*, 1986). Chorlton (1978) included gneiss and gabbro of the Cinq Cerf area in the Devonian or earlier Cinq Cerf Complex. Assuming an ophiolitic affinity, and an age younger than the Late Precambrian–Cambrian paragneisses with which its correlatives are imbricated in the Central Gneiss Terrane, Unit 1 is probably Early Ordovician or older (after S. O'Brien *et al.*, 1986; van Berkel *et al.*, 1986).

Metasedimentary schists (Unit 2). Unit 2 chiefly consists of semipelitic and pelitic schist that outcrops within the southeastern intrusive belt, and forms a large (about 3 km²) roof pendant in Unit 19 (compare Figures 2 and 3). Although rocks assigned to this unit occur in two separate parts of the map area, they may have once belonged to a continuous belt. In the roof pendant, the schist is interlayered with boulder metaconglomerate and screens of leucocratic microgranite that are similar to those in the northwestern belt. A schistosity is well developed parallel to generally flat-lying compositional bands. Pretectonic porphyroblasts in Unit 2 occur outside the contact hornfels developed in the aureole of Unit 19.

Unit 2 is in contact with Units 6, 13, 14, 17 and 19. The younger granitoids (Units 17 and 19) were emplaced into Unit 2 metasedimentary and microgranitic rocks after all the folds and foliations observed in the map unit had developed. The older granitoids (Units 13 and 14) were emplaced after the formation of the schistosity in Unit 2 but prior to subsequent folding (see Structural Geology). Unit 2 is separated from Unit 6 by mafic dikes.

Previous workers in the Grand Bruit–Cinq Cerf area have considered the schists here defined in Unit 2 as the highly metamorphosed equivalents of Unit 6 sedimentary rocks. Chorlton (1978) represented the schists as high-grade rocks of the Georges Brook Formation, whereas Cooper (1954) thought that they were higher grade versions of the basement rocks to his La Poile Group. On lithological and structural grounds the writer feels that Unit 2 is best compared with the amphibolite facies rocks northwest of the Bay d'Est fault zone. This holds despite the fact that Unit 2 is along strike from Unit 1 gneiss and schist in the southeastern intrusive belt.

Metasedimentary, meta-igneous and metavolcanic rocks (Unit 3). Unit 3 is only exposed north of the Bay d'Est fault zone, and contains, in order of decreasing abundance, boulder and cobble metaconglomerate, concordant screens of foliated pink microgranite, psammitic and semipelitic schist and metavolcanic schist. The conglomerate contains clasts of granitoids, felsic volcanic rocks and amphibolitized gabbro. Some boulders have pre-incorporation foliations. In the vicinity of Cinq Cerf Brook and its tributary (Figure 2), these lithological subunits dip gently and display a prominent schistosity lying parallel to the stratification. Staurolite and garnet porphyroblasts are locally observable. Unit 3 schist becomes steeply dipping near the subvertical Bay d'Est Fault (see Structural Geology).

The amphibolite facies rocks in Unit 3 are in fault contact with the greenschist facies rocks in Units 4, 11 and 12 (Figure 2, Table 1). Chorlton (1978) reports them to be also in tectonic contact with the intrusive rocks placed in Units 16 and 19 in this report. She considered rocks, here grouped as Unit 3, to belong to the Middle Ordovician Bay du Nord Group (Chorlton and Dallmeyer, 1986).

Undivided sedimentary and volcanic rocks (Unit 4). Unit 4 occurs in the northwestern extremity of the map area, but was not examined in detail during the 1986 field season. Where the map unit is tightly folded with Unit 16, it contains sedimentary rocks similar to those in Unit 6. Felsic pyroclastic rocks in the northern part of Unit 4 lithologically resemble rocks in Units 10 and 11. Future mapping is likely to result in redefinition of Unit 4.

The greenschist facies strata grouped in Unit 4 were intruded by Unit 16 and then faulted against Unit 3. Cooper (1954) and Chorlton (1980) placed the sedimentary and volcanic rocks in the uppermost part of the La Poile Group.

Mafic tuff and agglomerate (Unit 5). Unit 5 consists mainly of medium to fine grained, green, chloritic lithic tuff, and is exposed in the southwestern extremity of the map area. The southwesternmost tongue of Unit 5 is composed of agglomerate, containing centimetre- and decimetre-size bombs of dolerite or fine grained gabbro and blocks of pyroclastic material. Unit 5 is the only regionally mappable mafic volcanic unit in the Grand Bruit–Cinq Cerf area (compare with Swinden, 1984).

Unit 5 is not in contact with Unit 4, but it has conformable upper and lower contacts with Unit 6 (Table 1), within which it is entirely confined. Unit 5 agglomerate is overlain by a relatively thick sequence of felsic pyroclastic rocks belonging to Unit 6. Sedimentary rocks in Unit 6 stratigraphically underlie the mafic tuff. To the southwest, the lower contact between Unit 5 and Unit 6 is folded by doubly plunging, megascopic folds (see Structural Geology). Northeastward, the green tuff is gradually finer grained and is interbedded with thin sandstone. There, the unit splits to form two discrete bodies within Unit 6. Isolated green beds in the valley of Cinq Cerf Brook may be distal deposits related to a Unit 5 volcanic centre presently located to the southwest. The volcanic rocks in Unit 5 are not fed by the mafic dike swarms.

Unit 5 is a newly defined unit in the Grand Bruit–Cinq Cerf map area. Chorlton (1978) included the mafic tuff and agglomerate in the lower part of her undivided Georges Brook Formation. Cooper (1954) grouped them with the low-grade basement rocks to his La Poile Group.

Siliciclastic sedimentary and felsic pyroclastic rocks (Unit 6). Unit 6 occurs along the entire southeastern border of the central belt of stratified rocks and as smaller bodies within this belt (Figures 2, 3 and 4). In the southeastern outcrop belt, the lithology and structure of the unit vary considerably along strike. However, in all sections between Grand Bruit and Cinq Cerf, felsic pyroclastic rocks form the northwestern third of the map unit, whereas the remainder is chiefly composed of clastic sedimentary rocks.

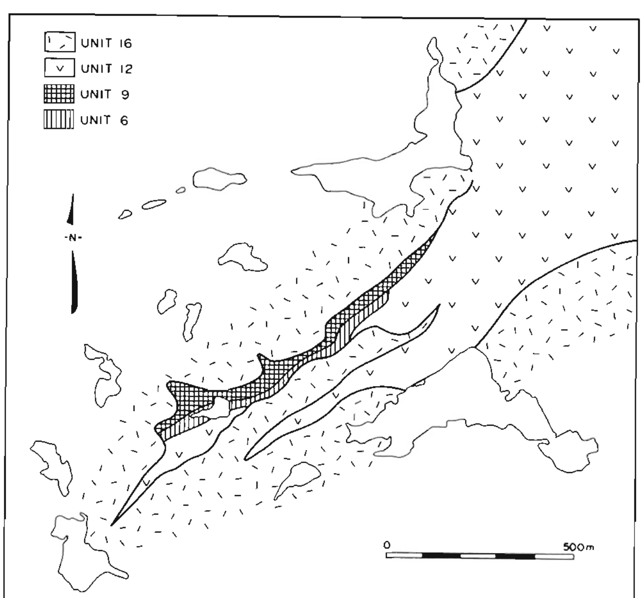


Figure 4: *Lithological map showing the distribution of Units 6, 9 and 12 near some of the narrow appendages of Unit 16. See Figure 3 for location.*

In the northeastern part of Unit 6 near Cinq Cerf Brook, green and pink-hued, lithic-crystal tuff is associated with oxidized red tuff and quartz-pebble conglomerate in a distinctive section that is less than 100 m thick. Southeastward, thin bedded, fine grained, buff-weathering, siliciclastic sandstone and argillite are increasingly abundant within the map unit. Where Unit 6 is relatively strongly deformed in the valley of Cinq Cerf Brook, thin units of very fine grained, pyroclastic rocks or epiclastic rocks rich in volcanic detritus are interlayered with the siliciclastic rocks.

To the southwest, in the Grand Bruit area, the lithic-crystal tuff associated with the distinctive red tuff is at least 400 m thick and directly overlies the mafic pyroclastic rocks of Unit 5. Southeastward, quartz-pebble conglomerate and polymictic cobble conglomerate are increasingly common at the expense of the thin bedded sandstone and argillite. Thick bedded conglomerate (Cooper's subunit 4a) forms the southeasternmost part of Unit 6 near Grand Bruit.

In Unit 6, the volume of the volcanic material, the grain size of the pyroclastic deposits, and the conglomerate : sandstone ratio of the sedimentary rocks increase to the southwest. Also, the degree of stratification decreases and the amount of imbrication increases in this direction. These observations indicate that the volcanic centre active during Unit 6 deposition lay closer to Grand Bruit than Cinq Cerf.

The southwestern outcrop area of Unit 6 is less strongly deformed than the northeastern outcrop area. Mafic hypabyssal intrusions increase in number and in volume toward the northeastern part of the unit, where they form swarms. This is away from the syndepositional volcanic centre, but toward the region of maximum deformation.

The smaller bodies of Unit 6 that occur within the central belt are composed exclusively of siliciclastic sandstone and argillite; felsic pyroclastic rocks are absent.

The largest outcrop belt of Unit 6 is in conformable contact with Units 7 and 9 to the northwest. Its southeastern contact is with granitoids of Units 13, 14 and 17 (Table 1). Right-way-up beds in a smaller belt of Unit 6 occur in the broad hinge zone of a gently southwest-plunging fold (Figure 2). Here, Unit 6 is in conformable contact with Units 8 and 10. A minute lenticle of Unit 6 is also found in contact with Units 9, 12 and 16 (see Figure 4).

Chorlton (1978) considered rocks here included in Unit 6 to represent the lowest exposed strata of the La Poile Group. Swinden's (1981) subunits 1B and 1C of the Georges Brook Formation would generally correspond with Unit 6 of this report, if one excludes his mafic rocks as a stratigraphical element. Unit 6 is the equivalent of Unit 4 of Cooper (1954), which he considered to be local basement to the La Poile Group.

Polymictic boulder conglomerate (Unit 7). Unit 7 is composed of several zones of polymictic, cobble and boulder conglomerate separated by sandstone, which underlie a series of prominent ridges northwest of Cinq Cerf Brook. Together, they form an excellent marker horizon. The conglomerate is highly deformed along its entire strike-length. Clasts of felsic and mafic volcanic rocks, granites and sedimentary rocks are most common, and clasts exhibiting pre-incorporation foliations also occur. Unit 7 terminates north of Grand Bruit near the thickest accumulation of Unit 6 pyroclastic rocks, and reoccurs in approximately the same stratigraphical position immediately southwest of the map area.

The contacts of Unit 7 with Units 6 and 9 are conformable. Cooper (1954) considered the boulder conglomerate and sandstone of Unit 7 and the red tuff and quartz-pebble conglomerate of Unit 6 to represent the basal beds of his La Poile Group. Similar, polymictic, cobble-dominated conglomerate containing foliated clasts occur, however, in Unit 6 as well as in other parts of the central belt of stratified rocks (Figures 3 and 5).

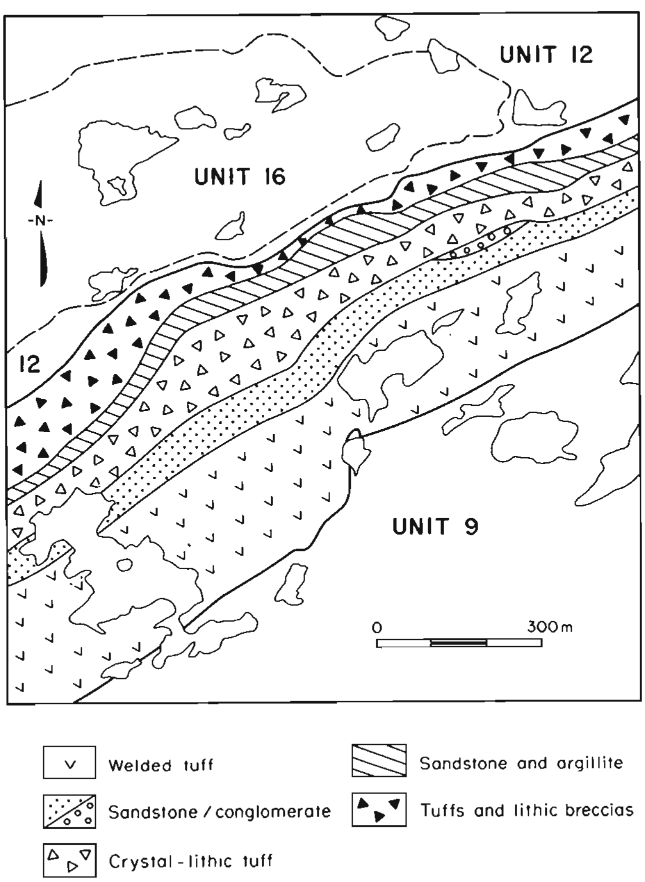


Figure 5: *Lithological map of a part of Unit 10. See Figure 3 for location.*

Flow-banded rhyolite (Unit 8). Being extremely resistant to erosion, Unit 8 rhyolite underlies the steep cliffs and highly dissected uplands at the southern boundary of the Highlands of Grand Bruit. It is pink, locally feldsparphyric and displays spectacular flow banding. Although flow banding is present throughout the map unit, it is best developed along its southeastern contact. Primary refolded isoclinal folds of banding indicate the viscous behaviour of the extrusion. Massive rocks are locally present near the northwestern boundary.

Regardless of position along either the northwestern or southeastern contact with Unit 9, Unit 8 rhyolite is always in sharp, conformable contact with 1 to 10 m of laminated argillite. Northeastward, the rhyolite terminates abruptly within Unit 9. This presumably marks the original extent of the flow as the map-unit closure does not appear to be a fold hinge (see Structural Geology). To the southwest, Unit 8 is folded with Units 6 and 10 in the hinge of a megascopic fold. The termination of Units 6 and 9 near this structure means that Unit 8 is brought in direct contact with Unit 10. Units 8 and 9 do not appear to be regionally repeated by the folding, although the relationship between Units 8 and 10 remains equivocal.

Unit 8 is a newly defined map unit in the Grand Bruit–Cinq Cerf area (Table 1). Previously, it had been grouped with other rocks in Chorlton's (1978) Georges Brook Formation and had been considered as Middle Ordovician (Loveridge and Chorlton, 1985; Chorlton and Dallmeyer, 1986).

Grits and wackes (Unit 9). Unit 9 extends the entire length of the central belt of stratified rocks, but is much more widespread in the northeast than in the southwest (Figures 2 and 3). This distribution pattern is probably primary. A small body of Unit 9 is found near Unit 16 (see Figure 4).

The map unit is generally composed of thickly bedded or poorly stratified, gray-weathering grits or wackes rich in volcanic detritus. The rocks are poorly sorted, rarely graded or cross-stratified, and interbedded with minor laminated argillite. Clasts are chiefly quartz and feldspar crystals, but large, foliated lithic fragments occur in places.

Unit 9 is in sharp conformable contact with Units 7, 8, 10 and 12. It is a newly defined unit in the Grand Bruit–Cinq Cerf map area that was previously included in the Middle Ordovician Georges Brook Formation (Chorlton, 1978). It is noteworthy that Unit 9 thins southwesterly toward the thickest accumulation of felsic volcanic rocks in Units 6 and 8, and thickens northeasterly, away from these rocks, into an area of relatively strong deformation.

Felsic pyroclastic and clastic sedimentary rocks (Unit 10). Unit 10 is a succession consisting mainly of felsic pyroclastic and clastic sedimentary rocks that occurs in the central belt of stratified rocks (Figure 3). It is widest near the western border of the map area, thins northeastward, and terminates near the northwestern tributary of Cinq Cerf Brook (Figure 2). In contrast to surrounding map units, Unit 10 comprises several distinctive lithological subunits that can be locally mapped on 1:10,000 scale. These are welded tuffs, which constitute the southeastern half of Unit 10, and interstratified tuff, breccia, sandstone, argillite and conglomerate, which form the northwestern part of the map unit (Figure 5). Polymictic conglomerate in Unit 10 contains clasts having pre-incorporation foliations, and, in this regard, is similar to rocks in Units 6, 7 and 9. The northwesternmost occurrence of a mafic dike is found in Unit 10.

Although the trace of the conformable contact between Units 10 and 9 outlines two megascopic folds, the former unit does not contain a regional fold closure (Figures 5 and 6).

Since its northwestern contact is nowhere faulted, the northeastern termination of Unit 10 is best explained by facies pinch-out. The Unit 10–Unit 16 contact is intrusive (Table 1).

Unit 10 is a newly defined map unit in the Grand Bruit–Cinq Cerf area and was previously included with other rocks in the Middle Ordovician Georges Brook Formation (Chorlton, 1978).

Lithic-crystal tuff (Unit 11). Unit 11 is monolithic, has limited outcrop in the northern part of the map area, and is poorly exposed relative to other map units. It is composed of light-green felsic tuff containing millimetre- to centimetre-scale, lithic and rarer crystal fragments.

Unit 11 appears to be in conformable contact with Unit 12, is assumed to be intruded by Unit 16, and is in fault contact with Unit 3. It is a newly defined map unit in the Grand Bruit–Cinq Cerf area. Chorlton (1978) grouped Unit 11 rocks in the uppermost division of her La Poile Group .

Rhyolite and rhyolite breccia (Unit 12). Unit 12, the most extensive stratified unit in the central belt, is mostly made up of massive and locally finely laminated, pink and cream rhyolite. Near its southwest boundary with Unit 16, Unit 12 contains highly deformed, coarse grained rhyolite breccia and tuff.

The contact between Unit 12 and the other stratified rocks in the central belt is apparently conformable. Its boundary with Unit 3 is a fault, whereas its locally folded contact with Unit 16 is intrusive (see Structural Geology).

Unit 12 is a newly defined map unit in the Grand Bruit–Cinq Cerf area. Chorlton (1978) formerly included it in the upper part of her La Poile Group.

Mafic dikes and sills (unseparated). Subvertical diabases oriented northeast and northwest are the most common hypabyssal rocks in and near the Grand Bruit and Cinq Cerf fault zones, although they are not shown in Figures 2 or 3. Emplaced during the regional deformation, these intrusions occur as sills where northeast-trending country rocks dip steeply; elsewhere, they are dikes.

Diabases are common to six map units belonging to the central belt of stratified rocks and the southeastern belt of intrusive rocks. They are metamorphosed to greenschist facies metabasite assemblages, and are variably deformed. In many places, metabasite dikes show structures indicative of autokinematic deformation.

The greenschist facies metabasites intrude amphibolite dikes in Unit 1. Where the former are strongly deformed in mylonite zones, the host amphibolite gneiss and dikes are retrogressed. Some diabases in Unit 6 near the Hope Brook Gold Mine are altered and contain deformed cordierite porphyroblasts.

Granodiorite (Unit 13). Unit 13 occurs as a lenticular body along part of the northwestern margin of the southeastern intrusive belt (Figures 2 and 3). It is a plagioclase-porphyritic, blue-quartz-bearing, biotite granodiorite, injected by swarms of metabasite dikes. It is generally devoid of xenoliths, although inclusions of schist and gneiss are located north of Unit 1 near Cinq Cerf Bay. The granodiorite is strongly foliated along its subvertical northwestern and southeastern margins, but is unfoliated in its central parts.

Unit 13 intrudes Units 1, 2 and 6, and is itself intruded by Units 14 and 17 (Table 1). It intruded Units 1 and 2 after the development of the schistosity and gneissosity, and intruded Unit 6 after the formation of slaty cleavage.

Cooper (1954) originally identified the granodiorite (Unit 13) as an unseparated phase of the Roti Granite, which he considered to be Devonian. Chorlton (1978) interpreted the Roti Granite as being subvolcanic to the Georges Brook Formation and thus implied that it was Middle Ordovician (Loveridge and Chorlton, 1985; Chorlton and Dallmeyer, 1986).

Porphyritic microgranite (Unit 14). Unit 14 occurs in the southeastern intrusive belt as three separate bodies in close spatial association with Unit 13 granodiorite (Figures 2 and 3). It also forms small hypabyssal intrusions in Unit 6, and possibly in Unit 1; these cannot be shown at map scale. Leucocratic, variably porphyritic microgranite is the chief rock type, although some textural variation is common. Leucocratic microgranites are, in places, either quartzphyric or feldsparphyric, and are associated with aplite or pegmatite. Near the margins of Unit 14, porphyritic microgranite forms a series of subvertical screens separated by variably deformed metabasite dikes.

At several contact localities, the southwesternmost body of Unit 14 crosscuts tectonically flattened conglomerate, yet it is apparently folded on a large scale with Unit 6 (Figure 2). In exposures closer to the Grand Bruit fault zone, Units 14 and 6 appear to be isoclinally infolded.

The central body of Unit 14 contains abundant septae of Unit 6 sandstone and argillite, as well as small screens of weakly foliated leucocratic microgranite that are apparently infolded with the host rocks. Where their contact is sharp, Unit 14 microgranite intrudes Unit 13 granodiorite.

The northeasternmost bodies of Unit 14 have accumulated along the flat-lying intrusive contact between Units 2 and 13. Vertical dikes of microgranite, porphyry and diabase share the same conduit in Unit 2 schist.

The porphyritic microgranites, here defined as Unit 14, were not previously separated from the Roti Granite by either Cooper (1954) or Chorlton (1978). Of all the rocks in the Grand Bruit–Cinq Cerf map area, the intrusions of Unit 14 are most closely associated with the greenschist facies metabasite dike swarms.

Gabbro and diorite (Unit 15). Unit 15 is confined to several small bosses or dikes, and is exposed near the western shore of Cinq Cerf Bay (Figures 2 and 3). It occurs wholely within Unit 13 in the southeastern intrusive belt. Immediately west of the map area, Unit 15 occurs within the extensions of Units 1 and 6. It is composed of equigranular, medium grained gabbro or diorite that is largely unfoliated and apparently unaltered.

The margins of Unit 15 are chilled and occupied by intrusion breccia. Weak, contact-parallel foliations are locally developed. Unit 15 crosscuts the foliation in Unit 13 granodiorite and the banding in Unit 1 gneiss inclusions.

Unit 15 is probably best correlated with the Siluro-Devonian Ernie Pond Gabbro of Chorlton (1978). Its relationship to the metamorphosed diabases is unknown, but these were emplaced and deformed in a similar fashion to the gabbro and diorite (see Structural Geology).

Granite porphyry (Unit 16). Unit 16, the most widespread unit in the map area, is restricted to the central belt of stratified rocks where it occurs as several discrete bodies intruding a variety of rocks. Unit 16 generally consists of fine grained granitic porphyry, which has slightly variable texture and color. It contains phenocrysts of rounded embayed quartz and green altered feldspar set in a microcrystalline, pink or reddish-brown matrix. Biotite occurs in many places.

Small, lenticular, northeast-trending, subvertical bodies of Unit 16 intrude Units 6, 7 and 9. Although locally altered or foliated, these intrusive rocks are generally unmetamorphosed and undeformed. On map scale, the porphyries transgress the steep contacts of Units 6, 7 and 9. At individual exposures, they intrude across inverted beds and early foliations in the stratified rocks.

The largest body of Unit 16 is steeply dipping and irregularly shaped. To the northwest, it intrudes Unit 4 and is faulted against Unit 3. Along its southeastern margin the intrusion crosses the conformable, steeply dipping contacts between Units 11 and 12, and between Units 10 and 12. Undeformed porphyry is commonly in direct contact with foliated country rock. Chilled margins are generally only a few centimetres wide.

Rocks here grouped in Unit 16 have been named the La Poile porphyry (Cooper, 1954) and the Hawks Nest Pond porphyry of the La Poile Group (Chorlton, 1978). They have been interpreted as pretectonic and synvolcanic–laccolithic respectively. A Siluro-Devonian age is likely (Table 1).

Granodiorite (Unit 17). Unit 17 is a large, lenticular, northeast-trending, subvertical body of medium grained, equigranular, biotite–hornblende granodiorite that occurs in the southeastern intrusive belt (Figures 2 and 3). It contains abundant cognate xenoliths and is intruded by swarms of greenschist facies metabasite dikes.

Undeformed Unit 17 granodiorite intrudes the gneissosity in Unit 1, the schistosity in Unit 2, and the foliation in Unit 13 granodiorite. Near Grand Bruit, contacts with Units 6 and 14 are marked by decimetre-wide zones of mylonite.

The granodiorite, here identified as Unit 17, was originally separated from Unit 1 by Cooper (1954). Chorlton (1978) chose, however, to group it within the Cinq Cerf Complex. Unit 17 may be equivalent to the earliest xenolith-rich biotite–hornblende granodiorite subphase of the Burgeo Granite (subunit 3a of S. O'Brien and Tomlin, 1985). It is also possible that it may be related to granodioritic rocks intimately associated with amphibole-bearing leucocratic migmatites (subunit 1a of S. O'Brien and Tomlin, 1985) that occur as kilometre-scale inclusions in the southern part of the Burgeo Granite.

Porphyritic granite (Unit 18). Unit 18 is the most outboard body in the southeastern belt of intrusive rocks (Figures 2 and 3). It is a medium to coarse grained biotite granite containing conspicuous, large (approximately 3 cm across) crystals of pink K-feldspar. Unit 18 contains abundant sheets of pegmatite, particularly near its margin. Near Grand Bruit the granite is not appreciably deformed, although strong, shear-related fabrics are present in the Cinq Cerf Bay area. Unit 18 intrudes Unit 17 along a boundary marked by highly folded pegmatites and strongly foliated, greenschist facies metabasite dikes.

The granite here referred to as Unit 18 was originally mapped by Cooper (1954), who called it the Grand Bruit batholith. It was renamed the Otter Point Granite by Chorlton (1978). Both workers thought that the map unit was correlative with the La Poile batholith, a granite postdating early structures in the Bay du Nord Group (Chorlton, 1980). In the Burgeo (11P/12) map area to the east, S. O'Brien and Tomlin (1985) have correlated the granitoid rocks on the east side of Otter Point with the main, early, biotite-rich granodiorite to granite phase of the Burgeo Granite.

Equigranular granite (Unit 19). Unit 19 is a large posttectonic pluton located in the eastern part of the map area (Figures 2 and 3). It discordantly intrudes map units belonging to both the central belt of stratified rocks and the southeastern belt of intrusive rocks. In contrast, swarms of posttectonic, northeast-trending, subvertical sills related to Unit 19 are preferentially emplaced near the Cinq Cerf and Grand Bruit fault zones, and extend for as much as 15 km southwest of the pluton.

Unit 19 is composed of distinctive, red, pink-weathering, medium grained, equigranular, biotite granite. The granite is fractured and altered but is nowhere foliated. An apparently high-level pluton, it contains inclusions of local country rocks at the border of the map unit, and a large roof pendant of Unit 2 near the centre of the body. Miarolitic cavities and pegmatites are also present. Hornfelses produced in the contact aureole of Unit 19 are best developed in Units 2 and 6, and are approximately 100 to 200 m wide.

Unit 19 is in intrusive contact with Units 2, 6, 7, 9, 12, 14, 16, 17 and 18 (Table 1). All map units were deformed prior to intrusion; contact metamorphism is static. Granite, here identified as Unit 19, has been referred to as the Chetwynd Granite (Cooper, 1954; Chorlton, 1978). $^{40}Ar-^{39}Ar$ spectra for biotite from the granite indicate an Early to Middle Devonian cooling age (Chorlton and Dallmeyer, 1986).

STRUCTURAL GEOLOGY

General Statement

Rocks in the Grand Bruit–Cinq Cerf map area have been inhomogeneously deformed. Variations in incremental

Table 2. Nomenclature and distribution of common deformation elements in metamorphic, stratified and intrusive rocks

Rock Type	Map Unit	Deformation					
		D_{1a}	D_{1g}	D_{2g}	D_{1d}	D_{2d}	D_{3g}
	Unit 18			S_{2g}			S_{3g}
Syntectonic	Unit 17			S_{2g}	S_{1d}		S_{3g}
intrusive	Unit 16			F_{2g}			
rocks	Unit 15			F_{2g}			
	Unit 14			S_{2g}	S_{1d}	S_{2d}	S_{3g}
	Unit 13			S_{2g}	S_{1d}	S_{2d}	$S_{3g}-F_{2g}$
	Unit 12		$S_{1g}-F_{1g}$				
	Unit 11		$S_{1g}-L_{1g}$				
	Unit 10		$S_{1g}-F_{1g}$	$S_{2g}-F_{2g}$	S_{1d}		
Low-grade	Unit 9		S_{1g}	$S_{2g}-F_{2g}$			S_{3g}
stratified	Unit 8		$F_{1g}-S_{1g}$				
rocks	Unit 7		S_{1g}	S_{2g}	S_{1d}		
	Unit 6		S_{1g}	$S_{2g}-F_{2g}$	S_{1d}	S_{2d}	$S_{3g}-F_{3g}$
	Unit 5		$S_{1g}-F_{1g}$		S_{1d}		
	Unit 4		S_{1g}				
High-grade	Unit 3	$S_{1a}-F_{1a}-L_{1a}$		S_{2g}(?)			
metamorphic	Unit 2	$S_{1a}-F_{1a}$		$S_{2g}-F_{2g}$	S_{1d}		S_{3g}
rocks	Unit 1	$S_{1a}-L_{1a}$		$S_{2g}-F_{2g}$	S_{1d}	S_{2d}	$S_{3g}-F_{3g}$

NOTES:

D_{1a} : syn-amphibolite facies deformation
D_{1g} : first greenschist facies deformation
D_{2g} : second greenschist facies deformation
D_{3g} : third greenschist facies deformation
D_{1d} : first (autokinetic) metabasite dike deformation
D_{2d} : second metabasite dike deformation

F : folds
S : cleavage, schistosity, gneissosity
L : lineations

D_{1d} and D_{2d} are syn-D_{2g}, pre-D_{3g} deformations. All pre-S_{3g} foliations in syn-D_{2g} intrusive rocks are termed S_{2g} despite differences in relative ages from unit to unit

and total strain are, however, manifested in different ways in each of the three regional belts of Lower Paleozoic rocks. In the central belt of low-grade stratified rocks, some units have been simply rotated about a fold axis and only weakly foliated, so that the original form and extent of local depositional basins can still be estimated. Other units in the central belt, however, have been extremely flattened and extended, but, internally, do not appear to be broken by faults or repeated by folds. Rocks in the central belt constitute a paratectonic terrane. In the northwestern belt of high-grade metamorphic rocks, as well as in the metamorphic inclusions in the southeastern belt, deformation has proceeded to the point where the protoliths of the gneisses are unrecognizable, and the original stratigraphic order of the schists is indiscernible. These rocks define the relics of an orthotectonic terrane. In the southeastern and central belts, intrusive rocks were emplaced and deformed during the regional deformation. Large variations in strain are particularly evident near the margins of the intrusive bodies. The majority of intrusions in the map area occur in or near major fault zones that separate paratectonic and orthotectonic terranes. Total strains are largest in the Grand Bruit and Cinq Cerf fault zones.

Greenschist facies metabasite dikes and sills occur exclusively in the vicinity of the Cinq Cerf and Grand Bruit fault zones, and play an important role in deciphering the structure of the map area. They intrude rocks as old and homogeneously deformed as Unit 1 and as young and inhomogeneously deformed as Unit 17. Mafic dikes and sills are utilized to separate a progressive, greenschist facies regional deformation into several increments of strain. The same could be said of the southeastern intrusive belt as a whole, although there the scale of the intrusions makes them less useful in mapping. The extent of dike or sill deformation permits a qualitative estimate of the magnitude of strain and identifies areas where fault movements were localized or protracted. In many localities, particularly where the total strain is large, the mafic intrusions are affected by country-rock deformation. However, autokinematic deformation confined to the metabasite dikes and sills is common, especially in areas where the total strain is small. The mode of emplacement and the metamorphic assemblages of these hypabyssal intrusions have a direct bearing on the kinematic, dynamic and thermal history of brittle–ductile fault zones in the map area.

Table 2 illustrates the types and relative ages of tectonic structures commonly observed in each map unit. The criteria used to separate deformation episodes in the Grand Bruit–Cinq Cerf map area are:

1) whether deformation was synchronous with amphibolite facies or greenschist facies regional metamorphism;

2) whether deformation of the stratified and metamorphic rocks predated or postdated that of the intrusive rocks;

3) whether deformation of the intrusive rocks affected the surrounding country rocks or was confined to the body of the intrusion.

Early, syn-amphibolite facies, regional deformation (D_{1a}) affects the high-grade metamorphic rocks of Units 1 to 3, but not the low-grade stratified rocks of Units 4 to 12 (Table 2). The former and the latter were probably initially juxtaposed during the first of three greenschist facies, regional deformations (D_{1g}, D_{2g} and D_{3g}). Coaxial $D_{1g}-D_{2g}$ and noncoaxial D_{3g} deformations affect the stratified rocks in the central belt. Where the total strain is large, all three deformations are superimposed; elsewhere, structures are predominantly of D_{1g} age. The regional D_{2g} deformaton was the first to affect all of the ductilely deformed map units (Units 1 to 18). Although the mafic dikes and sills were emplaced between the F_{1g} and F_{3g} folding events, the deformation of these intrusions was commonly autokinematic, and, therefore, is designated as D_{1d} rather than D_{2g}. Map units of syntectonic intrusive rocks were emplaced at various stages of a progressive D_{2g} deformation. Post-D_{1g}, pre-D_{3g} structures in the intrusions and in the surrounding country rocks are assigned to D_{2g}, despite differences in relative age from unit to unit.

In the following sections, the deformation of three belts of metamorphic, stratified and intrusive rocks is treated individually. The temporal and spatial development of structures is compared and contrasted in each belt.

Structures in Metamorphic Rocks

Introduction. Structures observable in high-grade metamorphic rocks (Units 1, 2 and 3) are divisible into those that formed during amphibolite facies regional metamorphism (D_{1a}) and those that formed during greenschist facies regional metamorphism (D_{2g} and D_{3g}). D_{1a}deformation of Units 2 and 3 involves recumbent folding and syntectonic intrusion of flat sheets of microgranite; the deformation style is very similar to that of the Bay du Nord Group in the eastern part of the Hermitage Flexure (Blackwood, 1984). In contrast, structures of D_{1a} age in Unit 1 are vertical, and are associated, in part, with the emplacement and deformation of ultramafic and mafic intrusions. D_{2g} deformation of Units 1 and 2 is confirmed by the structures of the mafic dikes and sills found in these units. Features of D_{2g} age in Unit 1 are associated with the retrogression of amphibolite gneiss, and the progressive metamorphism of greenschist facies metabasite dikes and sills. D_{2g} deformation of Unit 3 is only inferred (Table 2) because the unit is fault bounded and isolated from all other map units. If it is assumed that Units 2 and 3 both belong to the Bay du Nord Group, then this inference is enhanced. The effects of the D_{3g}deformation are only present in Units 1 and 2.

Detailed structure. Whereas major D_{1a} structures were not recognized, minor D_{1a} structures, including foliations, lineations and folds, do occur. In Units 2 and 3, where schists are regionally disposed in flatbelts and where the tectonic grain is either northwest or west respectively, minor F_{1a} folds are gently plunging and strongly overturned, axial planar S_{1a} foliations are gently inclined, and L_{1a} lineations plunge shallowly. Highly flattened conglomerate displays shape fabrics that exhibit a subhorizontal *XY* plane lying parallel to the micaceous, bedding-parallel S_{1a} mineral foliation in adjacent pelite and semipelite (Figure 6).

D_{1a} structures in Unit 1 include steeply plunging, minor F_{1a} folds, which are commonly boudinaged, and rare L_{1a} lineations. A considerable morphological variety of steeply dipping S_{1a} foliations occur. For example, margin-parallel schistosity in metagabbros concordantly intruding amphibolite gneiss and the gneissose banding in the host rocks are both grouped as D_{1a} structures.

D_{2g} structures, well displayed in Units 1, 2 and 3, are inhomogeneously developed but are invariably upright. Open, gently northeast-plunging, F_{2g} megascopic folds are outlined by the contact trace between Unit 2 and the granitoids of Units 13 and 14 (Figure 2). Second-order F_{2g} minor folds and third-order F_{2g} crenulations of schistosity are common in Unit 2 schist. In Unit 3, megascopic F_{2g} folds are generally open, upright and gently plunging to both the east and west (periclinal). Where D_{2g} deformation is weak, these folds deform the S_{1a} schistosity and previously flattened conglomerate so that they dip gently north and south (Figure 6). Complex $F_{1a}-F_{2g}$ interference patterns are produced (e.g., see Cooper's (1954) and Chorlton's (1980) maps immediately north of Cross Gulch on Cinq Cerf Brook). Along the northern side of the Bay d'Est Fault in the Grand Bruit–Cinq Cerf area and north of the map area in the extension of Unit 3, there are areas of relatively large D_{2g} strain characterized by east-trending, subvertical platy rocks (Figure 6). A penetrative, steep S_{2g} crenulation cleavage is axial planar to F_{2g} folds, which locally succeed in steepening the lithological and structural flatbelts in Unit 3. Tight, upright, F_{2g} minor folds of previously flattened clasts have their axes parallel to a strong, subhorizontal, L_{2g} extension lineation. The *XY* plane of the resultant shape fabrics in the highly deformed conglomerate is steep.

F_{2g} folds in Unit 1 are steeply or vertically plunging, upright and northeast trending. Near the Grand Bruit fault zone they are isoclinal; southeastward, open F_{2g} folds are more common. In the hinge zones of the open structures, subvertical, northwest-trending gneiss is discordantly intruded by foliated metabasite dikes emplaced parallel to the F_{2g} axial surface. Amphiboles in the gneiss are realigned parallel to the S_{2g} foliation in the host rocks and the marginal S_{1d} foliation in the dikes. Relatively large D_{2g} incremental strains make steeply plunging F_{2g} folds in Unit 1 isoclinal before passing into steep mylonite zones containing subvertical L_{2g} extension lineations. Within the mylonite zones, wall-to-wall-foliated, vertical, metabasite sills are folded by tight, extremely curvilinear, upright folds, and are locally crenulated by S_{2d} foliation. Because the F_{2g} fold plunge varies over short distances from subvertical to subhorizontal, the walls of the highly deformed, structurally concordant metabasites locally dip gently. In zones throughout Unit 1

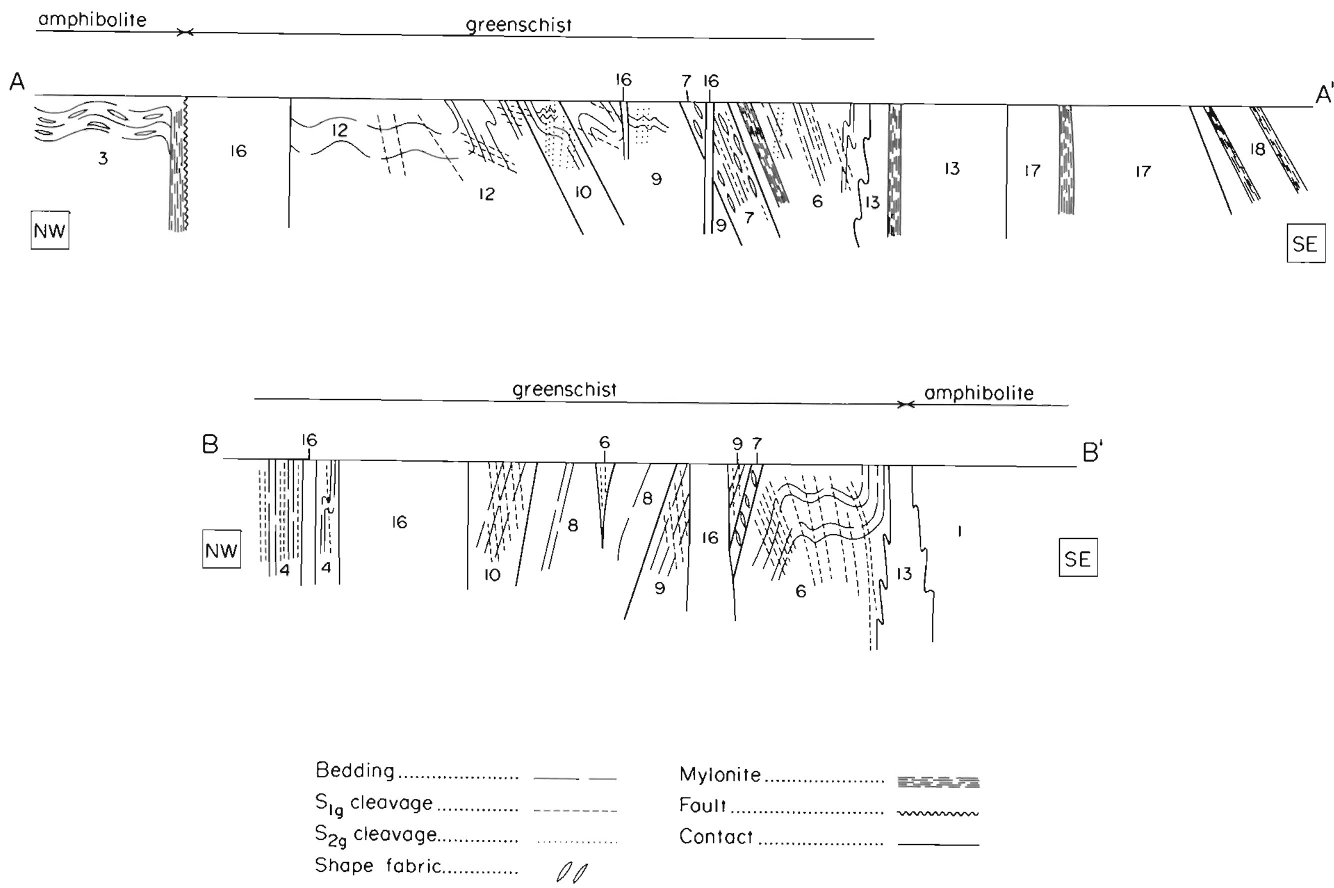


Figure 6: *Geological cross-sections of the Grand Bruit–Cinq Cerf area. See Figure 2 for location of section lines.*

where the total strain is large, it is difficult to distinguish the D_{1a} and D_{1d}–D_{2d} diking and foliation-forming events.

D_{3g} deformation is developed locally in the gneiss and schist of Units 1 and 2, where it affects the highly deformed, platy rocks in particular. D_{3g} structures include open, variably plunging, north-northwest-trending, steeply inclined F_{3g} cross folds and spaced S_{3g} crenulation cleavage.

Structures in Stratified Rocks

Introduction. Taken as a whole, the low-grade stratified rocks in the Grand Bruit–Cinq Cerf map area show structures typical of slate belts and simply folded belts (after Hobbs *et al.*, 1976; for an example, see B. O'Brien, 1986a). The dominant foliation is vertical S_{1g} slaty cleavage; gently plunging F_{1g} folds are developed on several orders of magnitude.

The bulk regional strain in the stratified rocks increases as follows: 1) to the northeast along the inverted, southeast limb of the La Poile syncline (Cooper, 1954), a first-order, gently plunging F_{1g} fold whose axial trace presumably lies outside the map area, and 2) to the southeast toward the Grand Bruit and Cinq Cerf fault zones. Platy stratified rocks are absent immediately south of the Bay d'Est fault zone, although this may be more apparent than real, as exposure is poor in this part of the map area.

The coaxial D_{1g} and D_{2g} deformations are difficult to distinguish in the southwestern part of the area near Grand Bruit because both deformation phases produce upright structures. Northeastward, in the vicinity of Cinq Cerf Brook, S_{2g} overprints S_{1g} and F_{2g} refolds F_{1g} as the D_{1g} and D_{2g} deformations cease to be coplanar. D_{3g} deformation is everywhere noncoaxial with respect to earlier structures and is responsible for regional swings in strike.

Greenschist facies metabasite dikes and sills intruded greenschist facies stratified rocks after the F_{1g} folds and the S_{1g} slaty cleavage had developed. They were emplaced and deformed during progressive D_{2g} deformation of the country rocks. In places, undeformed dikes intrude upright folds of older foliated dikes and their wall rocks.

Detailed structure (southwestern part of the central belt). In the extreme southwestern part of the Grand Bruit–Cinq Cerf area, Units 5, 6, 8, 9 and 10 are affected by second-order, map-scale, periclinal F_{1g} folds (Figure 2). Subvertical, axial planar, S_{1g} slaty cleavage is everywhere steeper than the bedding planes and faces upward in right-way-up, northwest-younging beds (Figure 6). Developed parasitically on the southeast limb of the La Poile syncline, all F_{1g} folds display dextral vergence and are gently plunging. Cooper (1954) suggested that the axial trace of the first-order fold lay within Unit 12 and Unit 16 (his La Poile porphyry). However, present mapping indicates that this interpretation is unlikely (Figure 6), and that strata on the northwest limb of the La Poile syncline are not found in the Grand Bruit–Cinq Cerf map area.

Third- and fourth-order F_{1g} folds developed in Unit 6 reflect increased regional strain in the southeastern part of the map area. Approaching the Grand Bruit fault zone, the plunge of the F_{1g} fold axes increases on the upright axial surfaces. Unit 6 conglomerate, containing S_{1g} shape fabrics that have subvertical *XY* planes, outline fold-like structures with unfoliated parts of the granitoid of Unit 14 (Figure 11). Within the Grand Bruit fault zone, vertical, northeast-trending, platy rocks in Unit 6 are isoclinally infolded with strongly deformed and vertically foliated parts of Unit 14.

Mafic dikes and sills intrude strata of Unit 6 in both the weakly deformed and strongly deformed parts of the map unit. Using the intrusions as strain gauges, the total strain in the southwestern part of the central belt is separable into two incremental strains, one pre- and one post-intrusion of the dikes and sills. In the area north of Grand Bruit where the total strain is small and the early strain increment can be demonstrated to be D_{1g} in age, the mafic intrusions show abundant evidence of autokinematic deformation. In the Grand Bruit fault zone, where the total strain is large, mafic sills are deformed with their country rocks in zones of relatively strong D_{2g} deformation.

Detailed structure (northeastern part of the central belt). As the D_{1g} strain increases northeastward, right-way-up strata in Units 6, 7, 8, 9 and 10 steepen from their predominant northwest inclination and dip vertically, displaying bedding-parallel S_{1g} slaty cleavage. Near Cinq Cerf Brook, the same vertical strata are overfolded and generally dip southeastward. In the highly strained conglomerate of Unit 7, the *XY* plane of shape fabrics and the S_{1g} cleavage lie parallel to bedding and dip moderately (Figure 6). Where rocks in Units 9 and 10 are less deformed, sedimentary structures indicate that the strata young to the northwest and are inverted. This is supported by the fact that the southeast-dipping S_{1g} foliation is inclined gentler than the bedding (Figure 6). The relation of S_{1g} cleavage to bedding in Unit 9 (Figure 6) negates the possibility of a map-scale F_{1g} fold closure within the unit near the termination of Unit 8 (Figure 2). Thus, it appears that the southeast limb of the La Poile syncline becomes inverted up-plunge in the direction of increasing strain, and that this regional northwest overturning of the first-order fold occurred during the development of the S_{1g} cleavage fan.

In the highly strained, overturned rocks immediately northwest of the Cinq Cerf fault zone, the angle of pitch of L_{1g} lineation on the southeast-dipping S_{1g} surface is large, although rarely observed. D_{1g} extension directions, obtained from fibrous syntectonic veins in highly flattened conglomerate clasts, indicate an extension (perpendicular to the *AC* plane) pitching moderately southwest on S_{1g}. Large D_{1g} strains on the overturned F_{1g} limb, therefore, accompany oblique-slip movements. Local evidence to show the relative motions of older and younger beds has not been found.

Whereas the regional D_{1g} deformation is relatively strong throughout most of the northeastern part of the central belt, the D_{2g} deformation of the stratified rocks on the overturned F_{1g} limb is notably inhomogeneous. Northwest of Unit 6, in a region of low D_{2g} strain, weakly developed D_{2g} structures coaxially overprint D_{1g} structures. Map-scale F_{2g} folds are outlined by the contact trace between Units 12 and 16, and between Units 9 and 10 (Figure 2). These northeast-trending folds deform a foliation in the granite porphyry, and the S_{1g} cleavage and bedding in the stratified rocks. Map-scale F_{2g} folds plunge gently or moderately to the southwest or the northeast. Megascopic and minor F_{2g} folds are best seen in Unit 9, especially near the contacts with small bodies of Unit 16.

A variety of northeast-trending, vertical S_{2g} foliations are present in rocks on the overturned limb of the La Poile syncline. A weak S_{2g} crenulation cleavage is steeper than bedding and faces downward in the inverted strata (see AA′ in Figure 6). In places, it crenulates S_{1g} foliation and is axial planar to open F_{2g} minor folds. Where vein arrays are locally well developed, a spaced S_{2g} solution-type cleavage is present. L_{2g} bedding–cleavage or cleavage–cleavage intersection lineations plunge gently to the southwest and northeast.

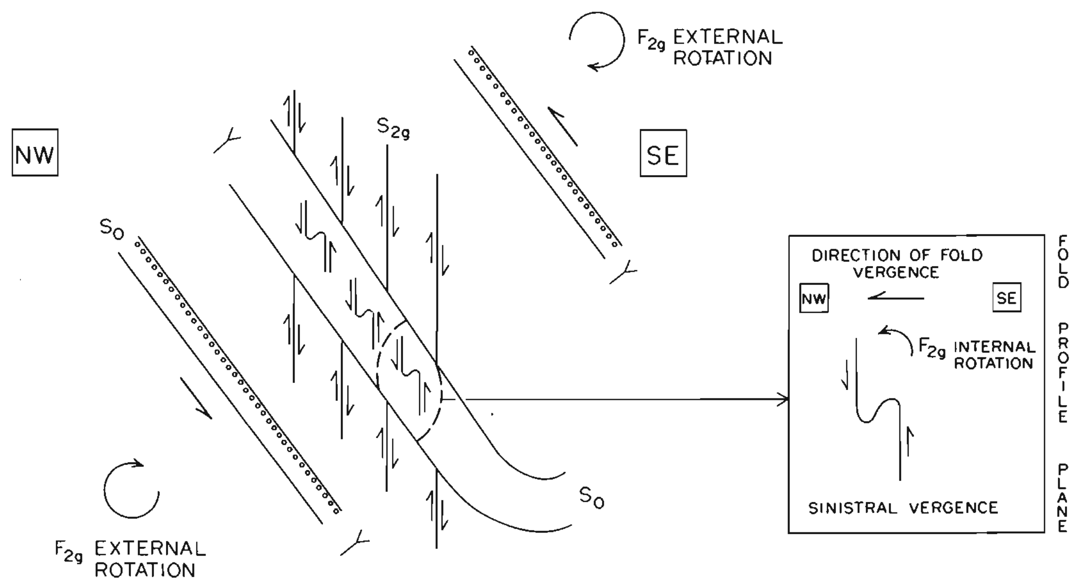
The vergence obtained from the S_{2g} cleavage–bedding and cleavage–cleavage intersections is consistent in all rocks on the inverted limb of the La Poile syncline, and is in agreement with the sinistral vergence of the less common F_{2g} minor folds (Figure 6). The direction of S_{2g} cleavage vergence and F_{2g} fold vergence (after Bell, 1981) is northwest (Figure 7). The theoretical, first-order structure is a downward-facing F_{2g} synform lying southeast of the central belt of stratified rocks. Thus, the regional F_{1g} and F_{2g} vergences oppose each other, and the structural or successional way-up on D_{1g} and D_{2g} features are completely different. The sense of shear associated with the external D_{2g} rotation (Figure 7) means that the southeastern intrusive belt has moved downward relative to strata occurring farther northwest (Figure 8).

D_{2g} deformation is notably strong in Unit 6 near the Cinq Cerf fault zone (Figure 8). Upright, northeast-trending, close to isoclinal F_{2g} folds deform penetrative S_{1g} bedding-parallel foliations and display vertical, axial planar S_{2g} crenulation cleavage. The highly curvilinear F_{2g} fold axes plunge both gently and steeply to the northeast and southwest in steeply dipping mylonites interlayered with platy stratified rocks. Some mylonites may have formed in Unit 6, but others have granitoid protoliths lithologically similar to Unit 14. The siliciclastic and felsic pyroclastic rocks of Unit 6 are not regionally repeated about the belt of strong D_{2g} deformation in the Cinq Cerf fault zone.

In the northeastern part of the map area, particularly in Units 6 and 9, weak D_{3g} deformation affects bedding and the S_{1g} and S_{2d} foliations. North-northwest-trending, steeply plunging, open F_{3g} cross folds and axial planar S_{3g} crenulation cleavage are present in places.

Summary of the central belt. Chorlton (1980), Chorlton and Knight (1983) and Chorlton and Dallmeyer (1986) have suggested that the La Poile and Bay du Nord groups have a common depositional and structural history. The upright D_{2g}

(a) F_{2g} FOLD VERGENCE IN VERTICAL PROFILE PLANE



(b) S_{2g} CLEAVAGE VERGENCE IN PLANE PERPENDICULAR TO L_{2g}

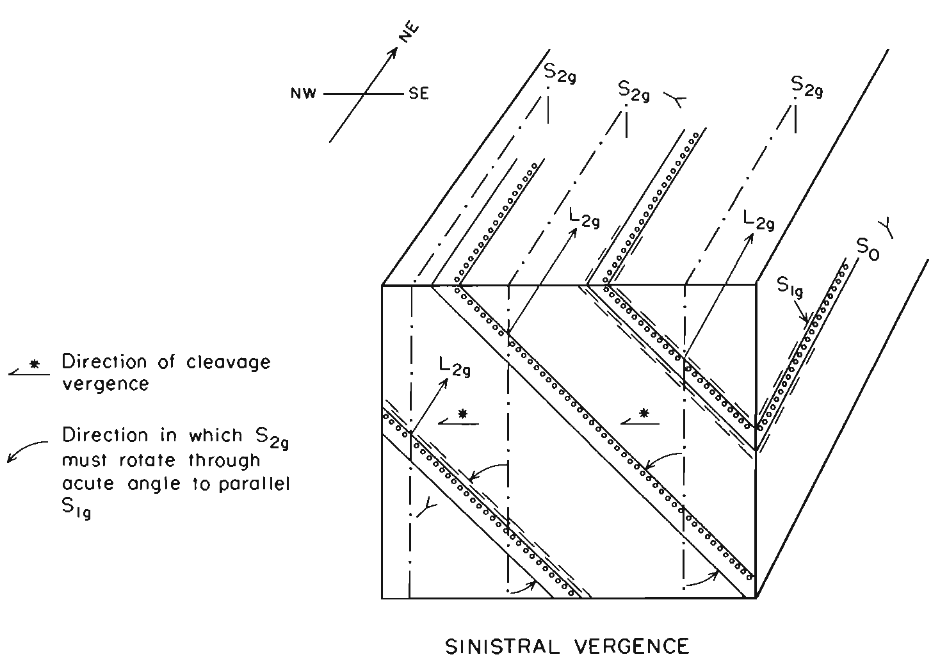


Figure 7: *Diagrams to illustrate fold and cleavage vergence in the Cinq Cerf Brook area: a) sinistral, northwest-verging F_{2g} folds; b) sinistral, northwest-verging S_{2g} cleavage.*

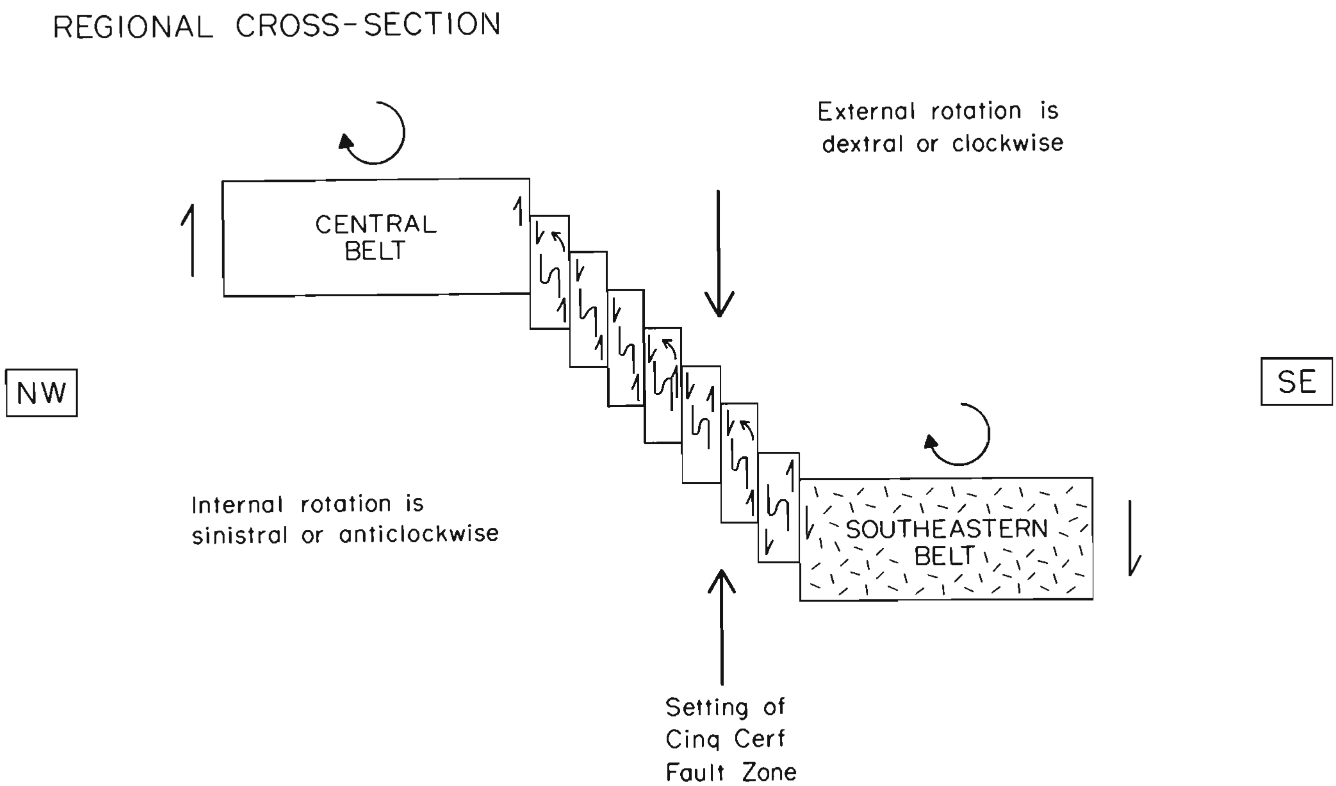


Figure 8: *Simplified, diagrammatic cross-section showing the relative movements of the central belt and the southeastern belt during D_{2g} deformation. Note the setting of the Cinq Cerf fault zone and the distinction between the external and internal rotation of these blocks.*

deformation in the stratified rocks probably correlates with the upright D_{2g} deformation in the metamorphic rocks. The relationship between the recumbent, amphibolite facies D_{1a} structures and the upright, greenschist facies D_{1g} structures is unknown because Unit 3 is fault-bounded. Inverted strata carrying moderately inclined, phyllitic, S_{1g} cleavage are separated from rocks containing gently dipping, coarse grained, S_{1a} schistosity by younger intrusions near the Grand Bruit and Cinq Cerf fault zones.

Structures in Intrusive Rocks

Introduction. Six map units of syntectonic intrusive rocks and unseparated swarms of mafic dikes and sills are found in the Grand Bruit—Cinq Cerf area (Figure 2, Table 1). All of these granitic and gabbroic rocks are deformed, northeast trending and steeply dipping. In the southeastern intrusive belt, inhomogeneous deformation is manifested by the presence of mylonites in intrusions that elsewhere preserve primary igneous textures. The central portions of map units are generally undeformed or weakly deformed, whereas their margins show typical protoclastic textures and large bulk strains. The oldest intrusive rocks intrude D_{1a} and D_{1g} structures in the central and southeastern belts. In a series of successive events, intrusions transected tectonic fabrics in host intrusions and were themselves subsequently deformed.

In the Grand Bruit—Cinq Cerf map area, zones of large total strain are host to a greater variety and a larger number of intrusions than zones that were never appreciably strained. During D_{2g} deformation, intrusions were emplaced into host rocks, and both were extended, folded and sheared, especially in the major fault zones. In the following section, the detailed structure of the mafic dikes and sills, and the extension, folding and shearing of intrusive rocks (using specified map units as examples) are discussed.

Structure of the mafic dikes and sills. Greenschist facies metabasite dikes and sills defining the borders of large (about 3000 by 300 m) swarms were first intruded where F_{2g} minor folds begin to overprint several orders of variably plunging F_{1g} folds. The greatest density of intrusions is located where platy or mylonitic host rocks are affected by relatively large D_{2g} strains. Of the two orientations of dikes and sills, those lying parallel to the regional foliation trace are generally more common.

Mafic intrusions, particularly those trending northwest, are autokinematically deformed (D_{1d}) in many places. Locally, especially if the total strain is small, dikes and sills show 1) sigmoidal, internal S_{1d} foliations, 2) syn-intrusion offset of markers in host rocks, and 3) high degrees of S_{1d} fabric anisotropy in isotropic country rocks. Although evidence to demonstrate a syn-D_{2g} intrusive age is found in Units 1 and 2, it is best seen in Unit 6 where that unit plunges gently northeast beneath Unit 5 north of Grand Bruit (Figure 2). At this locality, the mafic intrusions form the southwesternmost swarm in the Cinq Cerf fault zone and the northwesternmost swarm in the Grand Bruit fault zone. Vertical, northeast-trending intrusions occur as dikes in subhorizontal beds in

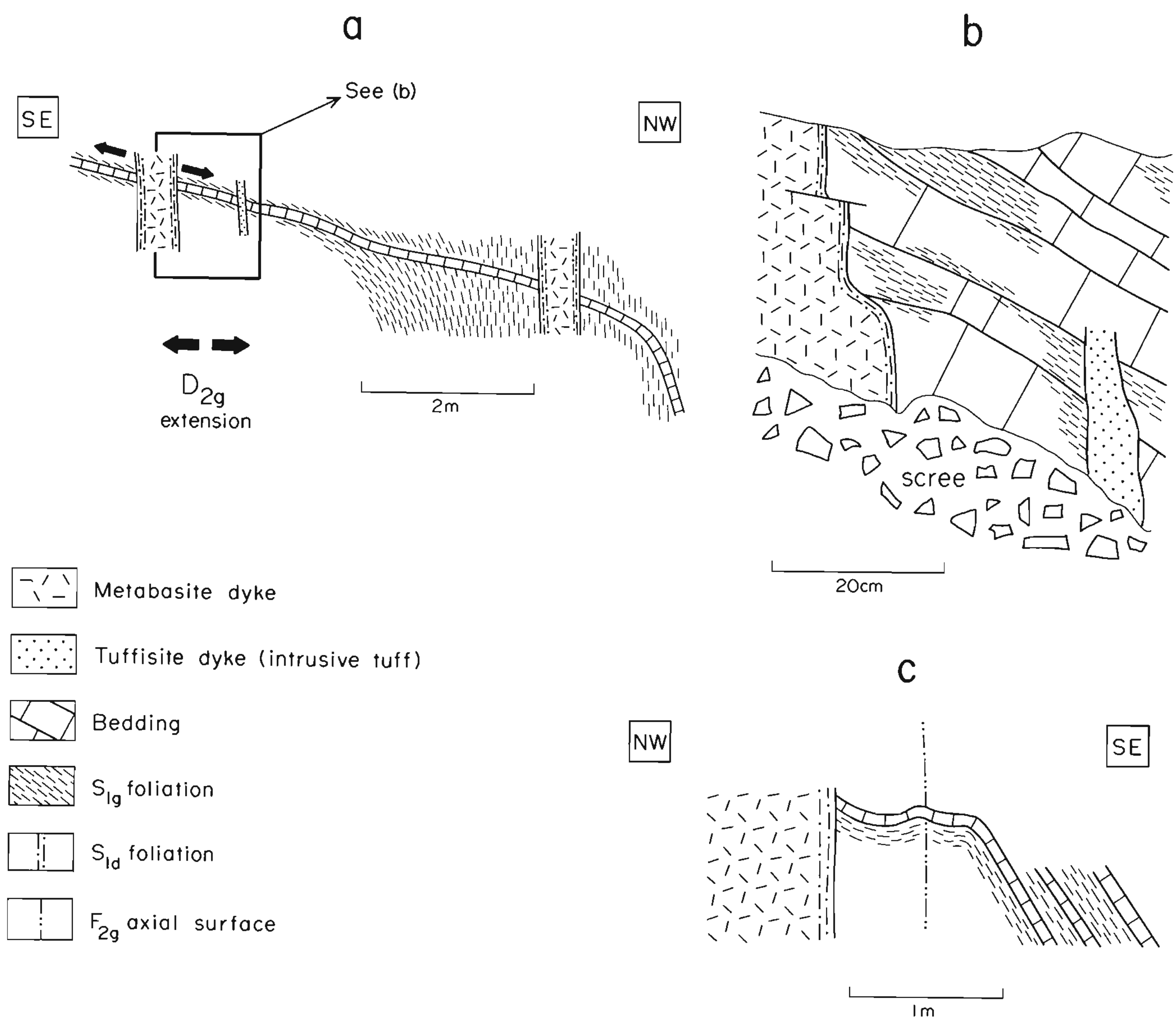


Figure 9: *Field sketches depicting D_{2g} structures near the margins of vertical dikes: a) geometry of the S_{1g} cleavage fan and its relation to bedding in the hinge of a F_{1g} megascopic fold intruded by tuffisite and metabasite dikes; b) closer view of (a) showing the low-angle S_{1g}–bedding relation near a marginally foliated diabase dike (EO843 N8282); c) marginal S_{1d} foliation in vertical dike is parallel to axial surface of locally developed F_{2g} fold of bedding and S_{1g} cleavage (E1770 N8617).*

broad F_{1g} hinge zones, and as sills within subvertical strata on F_{1g} fold limbs. The dikes are emplaced along the S_{1g} slaty cleavage in most places, and carry only a weak, contact-parallel S_{1d} foliation in the chilled margin. The main northeast set of dikes occupy the *AB* kinematic plane of the F_{1g} folds, whereas the rarer northwest set define the *AC* kinematic plane.

The timing of mafic intrusion relative to fold and cleavage development is determined from exposures like those depicted in Figure 9. Syn-D_{2g} horizontal extension resulted in localized ductile thinning of the strata in the hinges of the F_{1g} folds. It distorted and reoriented the S_{1g} slaty cleavage so that near the vertical walls of certain dikes the foliation lay subparallel to bedding (Figure 9). This ductile episode of D_{2g} extension predated 1) failure of the strata, 2) formation of vertical fractures, 3) infilling of fractures with diabase and dilation of the dikes, and 4) syn-dilation S_{1d} foliation development and related metamorphism. Nearby, dikes belonging to the same swarm are folded and vertically shortened by upright F_{2g} folds. In some localities, for some distance away from the dike wall, S_{2g} crenulations of bedding and S_{1g} cleavage occur parallel to S_{1d} (Figure 9).

Where country rocks are affected by large total strains, the northeast set of intrusions are far more abundant than the northwest set, and the sills are themselves very strongly deformed. Metabasite intrusions carry penetrative S_{1d} and local S_{2d} foliations, and are folded by tight, extremely curvilinear folds. Ductility contrasts between incompetent intrusions and competent hosts have caused boudinage and hard-grain deformation of platy country rocks. Strongly deformed swarms occur in Units 1, 6, 13, 14 and 17 in the Grand Bruit and Cinq Cerf fault zones.

Whereas mafic intrusions are interpreted to occupy *AB* and *AC* joints in the simply folded zones, the same rocks are apparently intruded along two sets of conjugate shear joints in the mylonite zones. The preferential development of the northeast set is noteworthy as the vertical intrusions are injected into planes perpendicular to the maximum shortening direction rather than parallel to it.

Intrusions affected chiefly by extension (Units 13 and 14). Unit 13 is the oldest map unit in the southeastern intrusive belt and is possibly the oldest map-scale intrusive body in the Grand Bruit–Cinq Cerf area. Together with Unit 14, it constitutes what previous workers called the Roti Granite (Table 1).

Unit 13 is a northeast-trending, lenticular body of granodiorite that has steeply dipping northwestern and southeastern contacts; quartz-ribbon, contact-parallel S_{2g} foliations are present at both margins. Internally, the granodiorite is relatively undeformed. At its southeast margin, Unit 13 intrudes subvertical mylonites in a D_{2g} high-strain zone developed along the margin of Unit 1, i.e., it intrudes some of the oldest fault rocks in the Grand Bruit fault zone. At its northwest margin, Unit 13 is injected into steeply dipping Unit 6 siliciclastic rocks along the bedding-parallel S_{1g} foliation, i.e., into strata that were inverted during D_{1g} (Figure 10). In the northeasternmost part of its outcrop, Unit 13 is emplaced into Unit 2 schist. There, the contact-parallel S_{2g} foliation in the granodiorite is generally flat and folded by open, upright F_{2g} folds.

Near the steep sides or walls of the granodiorite (i.e., the northwestern and southeastern contacts) D_{2g}, quartz-ribbon, LS fabrics formed as a result of a relatively large extension in the vertical plane. This also produced horizontal shortening localized near the margin of the intrusion. The upward flow of granodiorite magma in what is now the undeformed centre of Unit 13 was presumably aided by the anomalous amounts of vertical stretching that occurred in the Grand Bruit fault zone during inhomogeneous D_{2g} deformation. The flat-lying S_{2g} fabric observed in the top of the granodiorite (i.e., the northeastern contact) formed by horizontal extension or stretching localized along the contact with Unit 2. This probably indicates lateral flow of Unit 13 as it was emplaced beneath its subhorizontal roof of high-grade schist. Along a portion of the southeast wall of the intrusive body, Unit 13 fills fractures that lie parallel to banding in subvertical mylonites. These wall-rock contacts were either isoclinally folded by steeply plunging F_{2g} minor folds having an axial planar S_{2g} schistosity, or they originally formed as syn-D_{2g}, *en échelon,* linked cracks (Nash, 1979; Nicholson, 1985; Nicholson and Pollard, 1985). The steep tabular to slightly diapiric shape of Unit 13 is most probably an original D_{2g} feature (Figure 10).

Map-scale bodies of Unit 14 porphyry are present along the northwestern side and top of Unit 13. Small, unseparated, hypabyssal intrusions of Unit 14 occur in Unit 6 near the Cinq Cerf fault zone, and near Unit 1 in the Grand Bruit fault zone. Unit 14 is undeformed in most localities but locally it exhibits

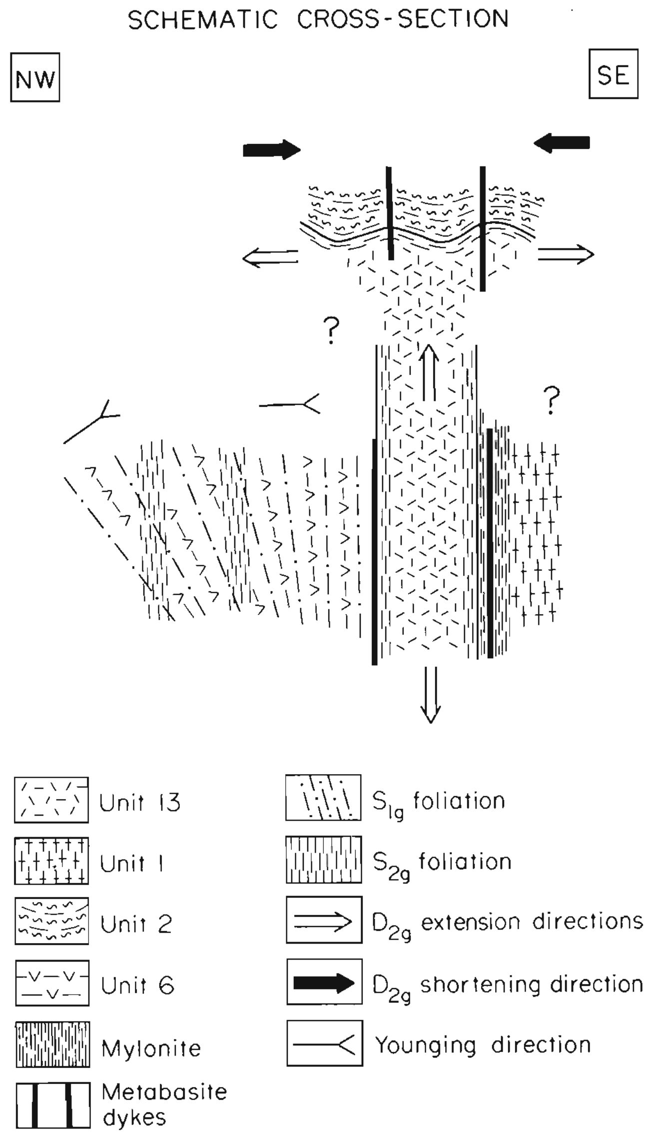


Figure 10: *Schematic, generalized cross-section across Unit 13 in the Cinq Cerf Brook–Cinq Cerf Bay area (not drawn to scale).*

a weak S_{2g} foliation. Where the contact is sharp, unfoliated microgranitic porphyries in Unit 14 are commonly intruded along or across strong S_{2g} foliation in the older granodiorite. However, in a few of the exposures near the mouth of Cinq Cerf Brook and beneath the Unit 2 contact, undeformed rocks in Unit 14 appear to pass gradationally from undeformed rocks in Unit 13.

The leucocratic microgranitic porphyry body (Unit 14) located near Cinq Cerf Brook contains numerous screens of Unit 6 siliciclastic rocks that carry a strong bedding-parallel, S_{1g} foliation. In plan, steeply dipping, northeast-trending screens of country rock are either totally enclosed in or tectonically interlayered with Unit 14. Near Grand Bruit similar relationships between Unit 14 and Unit 6 occur at map scale (Figure 11; B. O'Brien, 1986b). At many locations along the irregular contact between Units 14 and 6, porphyries in the former unit transgress the S_{1g} foliation in the latter unit. The

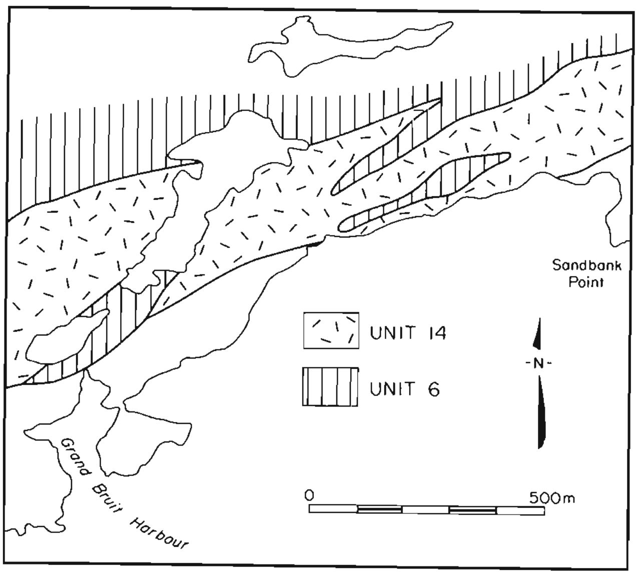


Figure 11: *Lithological map illustrating the relative distribution of Unit 6 and Unit 14 near Grand Bruit. See Figure 3 for location.*

contact trace outlines D_{2g} structures that are either tight F_{2g} folds or *en échelon*, porphyry-filled fractures (Figure 12) in which Unit 14 locally develops a weak S_{2g} foliation. This type of D_{2g} deformation is also common to the vertical margins of Unit 13 and Unit 14.

The northeasternmost bodies of Unit 14 were formed above the extended roof of Unit 13, and were injected as vertical dikes into the carapace of Unit 2 schist. They are spatially and temporarily related to the mafic dikes shown in Figure 10, so much so that in some places, Unit 14 porphyries occupy the central portions of composite mafic dikes. Locally, S_{1d} foliations in metabasites in the outer parts of composite intrusions are crosscut by younger non-schistose porphyries in the centre of the bodies.

Microgranitic porphyries in Unit 14 are generally younger than the post-D_{1g}, syn-D_{2g} granodiorite of Unit 13. Therefore, the Roti Granite as a whole is a composite intrusion in the map area. Development of S_{2g} foliation in the porphyries apparently overlapped the formation of the S_{1d} foliation in the mafic dike swarms. The younger phase of the Roti Granite would appear to have undergone less of the D_{2g} incremental strain than the host intrusion. The structure of Units 13 and 14 supports Cooper's (1954) hypothesis that the Roti Granite was intruded syntectonically during the regional upright folding of the La Poile and Bay du Nord groups.

Intrusions affected chiefly by folding (Units 15 and 16). The structures in Units 15 and 16 indicate the mode of emplacement and the role of contemporaneous extension and shortening in these syn-D_{2g} intrusive rocks. Like all the intrusions in the southeastern belt, gabbro and diorite of Unit 15 crosscut tectonic fabrics in older map units and are themselves deformed (Figure 13). The chilled margins of most bodies of Unit 15 gabbro show weak contact-parallel foliation similar to the S_{1d} fabric of the mafic dikes and sills. The commonly steep intrusive contacts are folded by open, gently plunging, northeast-trending F_{2g} megascopic folds so that they are locally flat-lying. In this regard, they are also comparable to some of the mafic intrusions in the vertical dike swarms. A strong S_{2g} shape fabric in Unit 13 granodiorite is oblique to the intrusive contact of Unit 15 (Figure 13a); however, near at least one of the steep contacts, it is locally reoriented into the plane of the margin-parallel foliation in the younger intrusion (Figure 13b). Material backveined from Unit 13 is deformed along with the gabbro in the foliated chilled margin.

The mechanism of emplacement of the small satellite bodies of Unit 16 porphyry located in the stratified rocks is similar to that of Unit 15. The largest of these northeast-trending, steeply dipping intrusions transects right-way-up, northwest-dipping beds near Grand Bruit and inverted, southeast-dipping beds near Cinq Cerf Brook (compare AA'

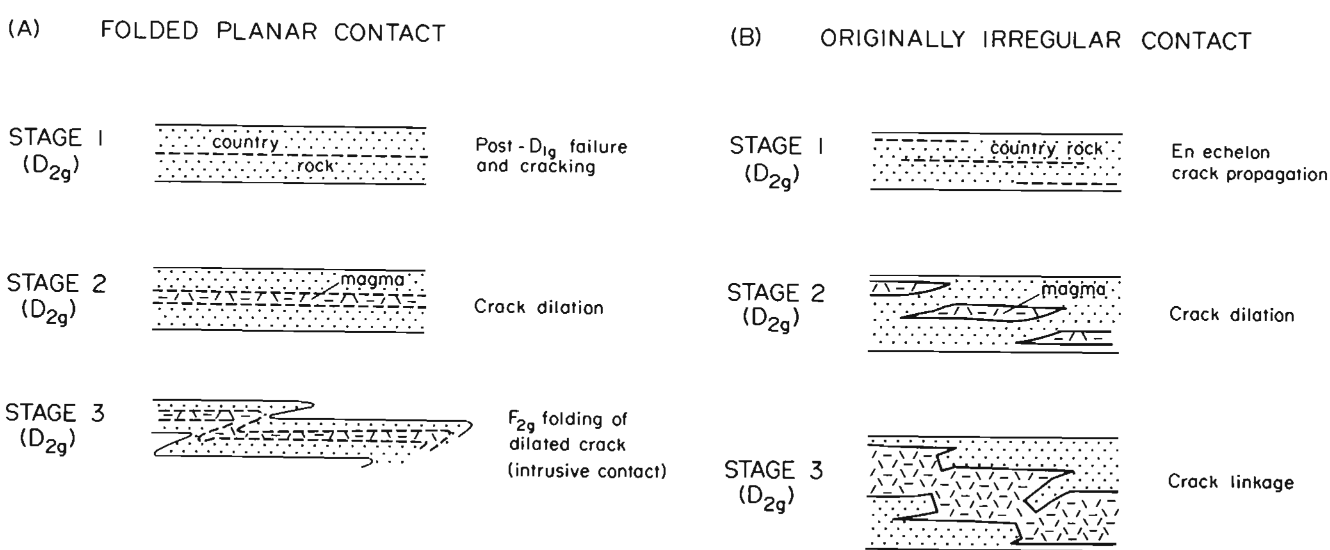


Figure 12: *Diagram showing two possible explanations of the observed shape of the contact between Unit 14 and Unit 6: a) folded planar contact; b) originally irregular contact (after Nicholson, 1985).*

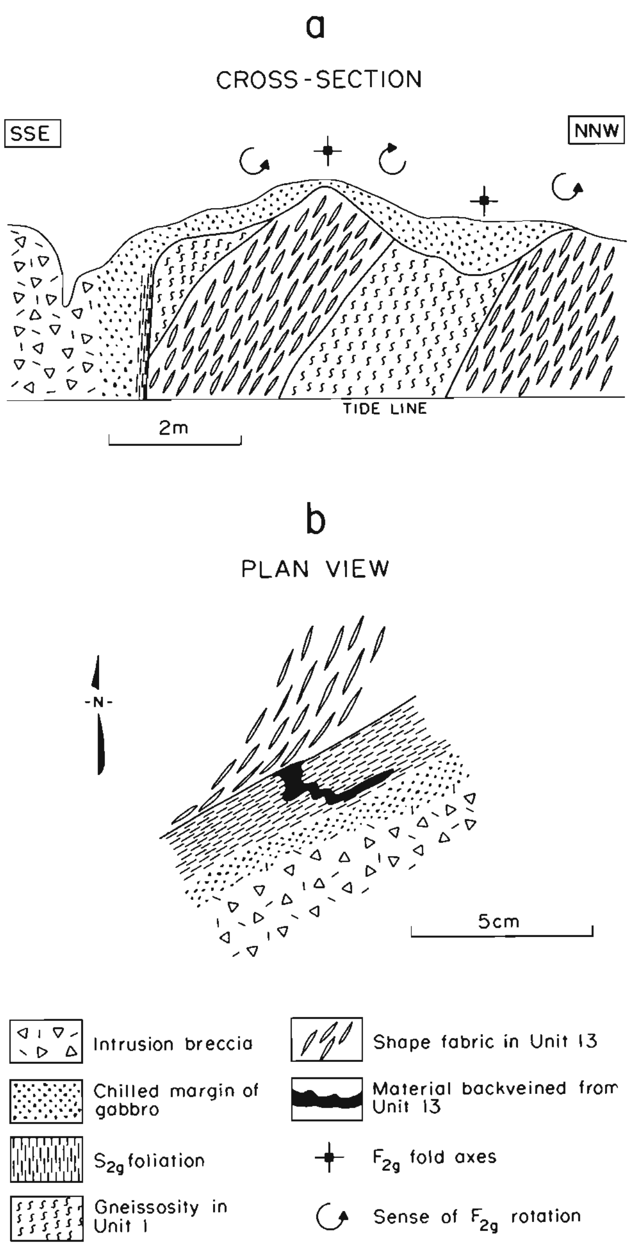


Figure 13: *Field sketches showing the structural and intrusive relationships of Unit 15: a) cross-section at E1470 N8217; b) plan view of steep contact at E1490 N8268.*

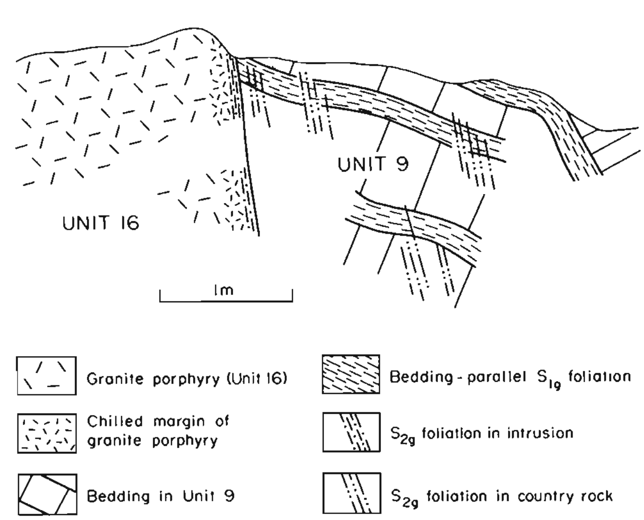


Figure 14: *Field sketch showing the structural and intrusive relationships of a Unit 16 dike emplaced into Unit 9 at E1513 N8620.*

and BB′ in Figure 6). Thus, vertical dikes of Unit 16 porphyry intrude the central belt of stratified rocks after the southeast limb of the F_{1g} La Poile syncline was inverted. This is in agreement with the common occurrence of unfoliated porphyry intruding strong S_{1g} foliations in the country rocks. In many places, the subvertical intrusive contact of Unit 16 is shortened by open, gently plunging, northeast-trending F_{2g} folds. In other localities, Unit 16 intrudes F_{2g} folds. There, the dike walls lie parallel to the locally developed S_{2g} foliation in the host rocks, and the porphyry has a weak coplanar foliation in the chilled margin (Figure 14). The near-perpendicular angular relationship between bedding-parallel S_{1g} foliation and the dike wall is due to either 1) local F_{2g} folding of bedding and S_{1g} cleavage prior to intrusion of the dike, and contemporaneous development of a margin-parallel foliation, or 2) horizontal ductile stretching of moderately inclined inverted beds into subrecumbent attitudes followed by dike intrusion, and then local D_{2g} shortening of dike and host rock.

The main, northeast-trending body of Unit 16 porphyry has several lobate appendages that intrude a number of stratified map units in the northern part of the central belt (Figures 2 and 5). The irregular intrusive contact of Unit 16 is folded in places, but is observed to be steeply inclined where the host rocks in Unit 12 dip gently in a large-scale F_{1g} fold (see section AA' in Figure 6). That the granite porphyry intruded the greenschist facies rocks after D_{1g} deformation is best seen in the narrow keel-like appendages near the Unit 12 contact (Figure 4). Here, relics of Units 6 and 9 are locally preserved between Units 16 and 12 along the wall of the intrusion. Bedding–S_{1g} cleavage–intrusive relationships indicate that Units 6, 9 and 12 were folded together, steepened to the vertical during D_{1g} deformation, and then intruded by Unit 16 along and across the tilted beds to produce the irregular contact trace (Figures 4 and 12). In these fold-like appendages, Unit 16 displays anomalously thick (10 to 30 m) chilled margins and locally penetrative S_{2g} foliation. Steeply plunging northeast-trending F_{2g} minor folds may be present in Unit 12 near these D_{2g} structures.

The southeasternmost appendage of Unit 16 porphyry is affected by relatively late-stage, large-scale F_{2g} folding. Northeastward from the point where Unit 16 transects the Unit 10–Unit 12 boundary (Figure 2), the intrusive contact dips southeastward, vertically and northwestward. Near the termination of the appendage, steep, contact-parallel S_{2g} foliation in Unit 16 and subvertical flow banding in Unit 12 are folded by large, open, northeast-trending F_{2g} folds so that they dip gently southwestward in the F_{2g} hinge zones. Variably steep- and shallow-plunging F_{2g} curvilinear folds of the walls of Unit 16 continue for some distance into the country rocks of Units 9 and 10.

Intrusions affected chiefly by shearing (Units 17 and 18). The granodiorite of Unit 17 and the granite of Unit 18 are the youngest syntectonic intrusions in the southeastern intrusive belt; however, their relationship to the syntectonic porphyries of Unit 16 is unknown. Inhomogeneous D_{2g} deformation is marked by discrete mylonite zones or by broader zones of ductile shearing near the common border of the map units.

Along the northwestern steeply dipping margin of Unit 17, undeformed granodiorite contains spherical cognate xenoliths. West of Cinq Cerf Bay, Unit 17 posttectonically intrudes D_{2g} platy rocks in the Grand Bruit fault zone near the Unit 1 – Unit 13 contact. North of Cinq Cerf Bay, unfoliated granodiorite cuts across S_{2g} schistosity in Unit 13.

Southeastward across Unit 17, narrow, sharply bounded, discontinuous bands of protomylonite and mylonite dip vertically in undeformed granodiorite (Figure 6). A penetrative S_{2g} schistosity and a coplanar shape fabric defined by highly elliptical cognate xenoliths is developed in the unit approximately 1 km from its southwestern contact. In the northwestern part of Unit 17, greenschist facies metabasite dikes display autokinematic S_{1d} foliation in unfoliated host granodiorite. Where the host rock is strongly deformed, however, the metabasite dikes occur in swarms, are penetratively foliated and are folded by tight, steeply plunging, northeast-trending F_{2g} folds. Swarms that are 0.5 km or less from the southeastern contact of Unit 17 locally contain netveined dikes, illustrating schlieren texture, that are syntectonically intruded by hornblende-bearing granodiorite.

The contact between Units 17 and 18 dips steeply southeastward (Figure 6) and is marked by a swarm of foliated, greenschist facies metabasite dikes. Near this boundary, the main phase of gray feldspar-megacrystic granite in Unit 18 is intruded by a pink feldspar-porphyritic phase associated with pegmatite and aplite. The younger phase of Unit 18 occupies *en échelon* fractures in the older phase, is injected along strong northeast-trending S_{2g} schistosity in the main granite, and is weakly foliated, in places, by pre-F_{3g} fabrics. This is a similar relationship to that between the Unit 13 and Unit 14 phases of the Roti Granite.

The *S* plane in the gray feldspar-megacrystic granite is defined by an alignment of biotite, the development of quartz ribbons and the elongation and flattening of xenoliths. The S plane commonly forms a discernible angle with subvertical, millimetre-scale bands of mylonite (i.e., the *C* planes of Berth *et al.*, 1979). The *C-S* fabrics are kinked and cross folded by F_{3g} folds. They indicate pre-D_{3g}, late syn-D_{2g}, dextral, strike-slip movements in the southeastern intrusive belt.

SUMMARY AND CONCLUSIONS

1. Greenschist facies, volcanic and sedimentary rocks in the central belt comprise eight, conformable, lithostratigraphical map units. Several of these units are in direct contact with two or more other units; one-sided units (regional fold closures) are absent. The outcrop pattern is essentially explained by lateral pinch-outs coupled with probable stratigraphical recurrences of certain lithofacies (e.g., Unit 6). Angular unconformities are not observed within the central belt, although there are repeated occurrences of polymictic conglomerate containing clasts exhibiting pre-incorporation foliations. The pretectonic, synvolcanic, high-level intrusions previously reported within the extrusive rocks (i.e., the Roti Granite and the Hawks Nest Pond porphyry) are syn-D_{2g} in age.

2. Strata in the central belt display primary sedimentary and volcanic structures that indicate terrestrial or shallow-water deposition. Felsic volcanic rocks are common in Units 6, 8, 10, 11 and 12, whereas mafic volcanic rocks are restricted to Unit 5. Felsic extrusive rocks are made up of approximately equal proportions of volcanoclastic deposits and lava flows. Associated sedimentary facies are admixtures of siliciclastic and epiclastic rocks. Pyroclastic and clastic rock units vary more in grain size and thickness laterally than they do vertically. The upper and lower boundaries of map units are drawn either where there are first-order differences in rock type (e.g., rhyolite and wacke), or where there are regionally abrupt changes from felsic flows to felsic pyroclastics. Internally, units locally show contrasts in color, texture, grain size and mineralogy.

3. Amphibolite facies metamorphic rocks in the northwestern and southeastern belts are unlikely to be the higher grade equivalents of the rocks in the central belt. The presence of conglomeratic and felsic pyroclastic layers in Units 2 and 3 seems fortuitous, unless structures in Unit 6 are of a different age and unrelated to structures in Units 7 to 12. It appears, however, that D_{1a} structures in amphibolite facies metamorphic rocks are not shared by rocks in any of the other map units in the Grand Bruit – Cinq Cerf area (Table 2). Schist and gneiss units are either juxtaposed against greenschist facies stratified rocks in the Bay d'Est fault zone, or located within younger intrusive rocks in the Grand Bruit fault zone.

4. The structural development of the Grand Bruit – Cinq Cerf map area is directly related to the evolution of local faults in the Hermitage Flexure system. Incipient movements in the fault zones probably occurred during the D_{1g} deformation. The overturning of the southeast limb of the La Poile syncline and the local development of southeast-inclined F_{1g} minor folds presumably heralds the translation of schist and gneiss relative to the stratified rocks. Displacement occurred as the greenschist facies rocks were being metamorphosed, i.e., movements were synchronous with S_{1g} cleavage development. During D_{1g} deformation either the amphibolites were overthrust northwestward onto the greenschists or the greenschists were underthrust southeastwards under the amphibolites. The presence of climactic assemblages in the greenschists and partially retrogressed assemblages in the previously deformed amphibolites may suggest the former. There is uncertainty, however, whether it is the high-grade or the low-grade rocks that are allochthonous in the map area. Contractional faults responsible for this regional D_{1g} imbrication are not directly observable in the Grand Bruit or Bay d'Est fault zones due to the effects of later deformation and intrusion. Outside the fault zones, the D_{1g} deformation was regionally upright and produced the typical periclinal folds found in slate belts.

5. Inhomogeneous D_{2g} deformation was regionally coaxial with the D_{1g} deformation and formed upright structures throughout the entire Grand Bruit—Cinq Cerf map area. The incremental D_{2g} strain was, however, largest within the major fault zones and small or absent away from them. By the end of D_{2g} deformation, rocks in the map area reflected the geometry of a vertical shear belt, with the low-grade strata in the central belt occupying a mega-augen. Differential dip-slip movements on vertical structures in the Grand Bruit and Cinq Cerf fault zones resulted in relative offset of the central and southeastern belts, but caused neither an extension nor a contraction of these crustal blocks. Horizontal syn-D_{2g} stretching of the blocks was achieved instead by brittle and ductile deformation associated with the emplacement of magma.

6. All the intrusive map units, most or all of the greenschist facies metabasite dikes, and some of the quartz veins in the central and southeastern belts were intruded after the regional D_{1g} deformation. They were emplaced and deformed during the regional D_{2g} deformation. Local and map-scale F_{2g} folds and variably penetrative S_{2g} foliations are most common near the margins of intrusions where, locally, they also affect a variety of country rocks.

7. Beds in the hinges or on the limbs of F_{1g} folds exhibiting distorted S_{1g} cleavage fans have locally undergone a permanent strain near vertical dike walls related to the dilation of mafic intrusions. Pre-emplacement strains were presumably recoverable where the only evidence of D_{2g} deformation is marginal contact-parallel foliations and F_{2g} folds of the dikes. Post-F_{1g}, pre-F_{2g} horizontal stretching is the cause of early viscoelastic deformation near the dikes. Syn-D_{2g} horizontal extension produces not only vertical, northeast-trending, diabase- and porphyry-filled fractures near the diapiric roof of the Roti Granite, but also the local development of a flat-lying S_{2g} foliation in the outer part of the intrusion.

8. Throughout most of the D_{2g} deformation, horizontal shortening was accomplished by a relatively large vertical extension. In highly strained rocks, D_{1a} and D_{1g} structures are reoriented into the vertically plunging D_{2g} extension direction. For the most part, syn-D_{2g} intrusions are internally undeformed but have vertical, strongly deformed margins exhibiting contact-parallel S_{2g} foliation. Continuous vertical extension of the syntectonic intrusive suites is responsible for shortening the subvertical marginally foliated intrusions and their wall rocks so that both are locally flat lying as a result of folding. Steep, progressively younger, deformed intrusions were injected into rocks that had been already vertically shortened by D_{2g} deformation. In the case of composite intrusions, growth or widening of the intrusive bodies was syntaxial, extension was episodic and magma ascent was periodic.

At certain times during the emplacement of the syn-D_{2g} intrusions, the extension direction was horizontal, for example, when failure resulted in the development of vertical fractures or when the host rocks were subsequently dilated. More specifically, extension was horizontal when the F_{1g} fold hinges and the roof of the Roti granodiorite were stretched to create space for swarms of hypabyssal intrusions. Simultaneous or cyclic periods of horizontal shortening and extension counteracted each other, so that as new magmas were added to the centre of the intrusions, a corresponding shape change occurred at the protoclastic margins. By the time Unit 18 was emplaced, strike-slip movements had replaced dip-slip movements in at least part of the vertical shear belt.

9. Evidence to suggest that post-F_{1g}, pre-F_{2g} extension was oblique rather than orthogonal comes from parts of the central belt of stratified rocks. Here, for example at the Unit 9—Unit 10 contact, F_{2g} folds and S_{2g} cleavage locally overprint D_{1g} structures non-coaxially. Oblique, syn-D_{2g}, horizontal extension had apparently rotated steep northwest-dipping beds and vertical S_{1g} cleavage out of the regional grain prior to the development of northeast-trending F_{2g} folds and S_{2g} cleavage. In areas where D_{2g} extension is small or absent and where F_{1g} folds are not inclined, D_{1g} and D_{2g} structures are coaxial and coplanar.

10. Magma-filled syn-D_{2g} fractures formed subparallel to S planes and were preferentially injected along the main anisotropy in the host rocks. The larger the bulk strain, the greater the density of vertical, northeast-trending intrusions. Northwest-trending intrusions are most common near the outer margins of swarms, where the total strain decreases. Syn-D_{2g} intrusions locally occupy extensional shear fractures in the southeastern and central belts.

11. Whereas the Grand Bruit fault zone is largely occupied by major composite intrusions, the Cinq Cerf fault zone contains only satellite bodies of porphyry and diabase at the present erosion level. Large, brittle displacements postdating the intrusion of Unit 19 affect the Bay d'Est fault zone, although there is some evidence of syn-D_{2g} strike-slip movements. The Bay d'Est structure can be traced eastward to the northern margin of the Burgeo Granite, where the geology is very similar to that observed in the southeastern intrusive belt (S. O'Brien, personal communication 1986).

12. The regional D_{3g} deformation produced the Z-shaped flexures of map units and faults in the Grand Bruit—Cinq Cerf area.

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