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GEOLOGY OF THE EASTPORT (WEST HALF) MAP AREA, BONAVISTA BAY, NEWFOUNDLAND

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ABSTRACT

Exposures of Precambrian rocks in southwestern Bonavista Bay form the northernmost terminus of the Avalon Zone in the Appalachian Orogen. Variably strained, greenschist-facies volcanic rocks of the Love Cove Group are exposed in an overturned anticlinorium. Marine siliciclastics and shaley rocks of the Connecting Point Group are exposed in a broad asymmetrical synclinorium paired to the anticlinorium. The lowermost stratigraphic level of the Connecting Point Group is in contact with the Love Cove Group on the common overturned limb of the synclinorium–anticlinorium pair. The contact is a fault of unknown displacement. The proportion of volcanic rocks within the Connecting Point Group increases stratigraphically downward toward the contact with the Love Cove Group, possibly indicating an originally conformable relationship between the two groups. Within the map area, the Musgravetown Group truncates the regional strike of the Connecting Point Group; an angular unconformity separating the Musgravetown Group from the underlying Connecting Point Group is exposed immediately south of the map area, at Clode Sound. The stratigraphic relationship between the Love Cove and Musgravetown groups is equivocal, but most field observations suggest an unconformity separates the Musgravetown Group from the underlying Love Cove Group. All stratified units host sulfide mineralization. Newly discovered silicified alteration zones within the Love Cove Group have elevated gold values.

INTRODUCTION

This paper summarizes the initial findings of a new, two-year project aimed at completing 1:50,000 scale mapping and related stratigraphic, structural and whole-rock geochemical studies of the northwesternmost exposures of Avalonian rocks in Newfoundland. The work is done in conjunction with a program of detailed logging of lithostratigraphy and sedimentology of the Connecting Point Group by I. Knight of the Newfoundland Department of Mines and Energy. The project area includes much of the Eastport (2C/12) and St. Brendan's (2C/13) map areas, and offers excellent exposures of the major geological units of the western Avalon Zone. In 1986, field work was carried out mainly in the west half of the Eastport map area (Figure 1).

Physiography

The dominant physiographic feature of the area is its deeply embayed, emergent coastline. The topographic relief is subdued, and elevations rarely exceed 150 m; the highest hills are remnants of a 250- to 300-m peneplain. The generally northeast-trending physiographic grain partially reflects glacial features, but it is mostly influenced by faults and the homoclinal nature of much of the sedimentary bedrock. Glacial striae and erosional landforms indicate east-northeastward to eastward movement of ice. Glaciofluvial complexes form the main surficial deposits and comprise extensive areas of outwash sand and gravel that terminate in sandy deltaic deposits whose upper delta surfaces reach 30 m in elevation.

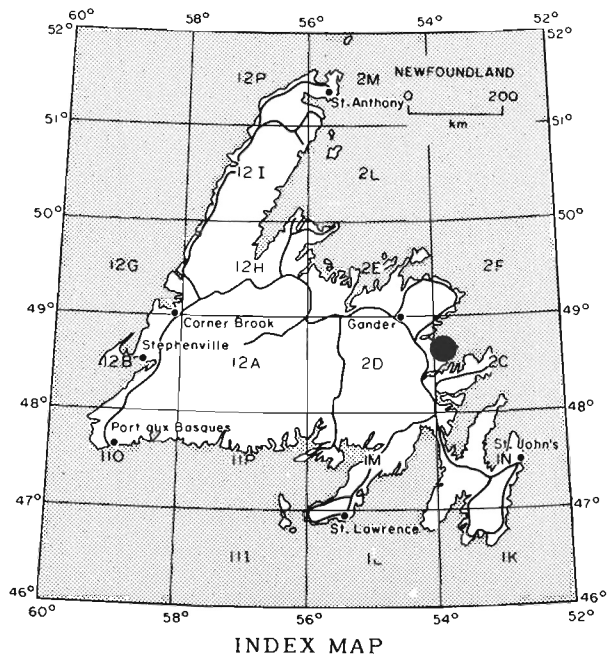

Figure 1: *Location of the Eastport (2C/12) map area.*

Previous Work

Southwest Bonavista Bay has been the focus of geological study periodically since 1842, when J.B. Jukes first identified the major geological units of the area (Jukes, 1843). In 1869,

This project is a contribution to the Canada–Newfoundland Mineral Development Agreement, 1984–1989

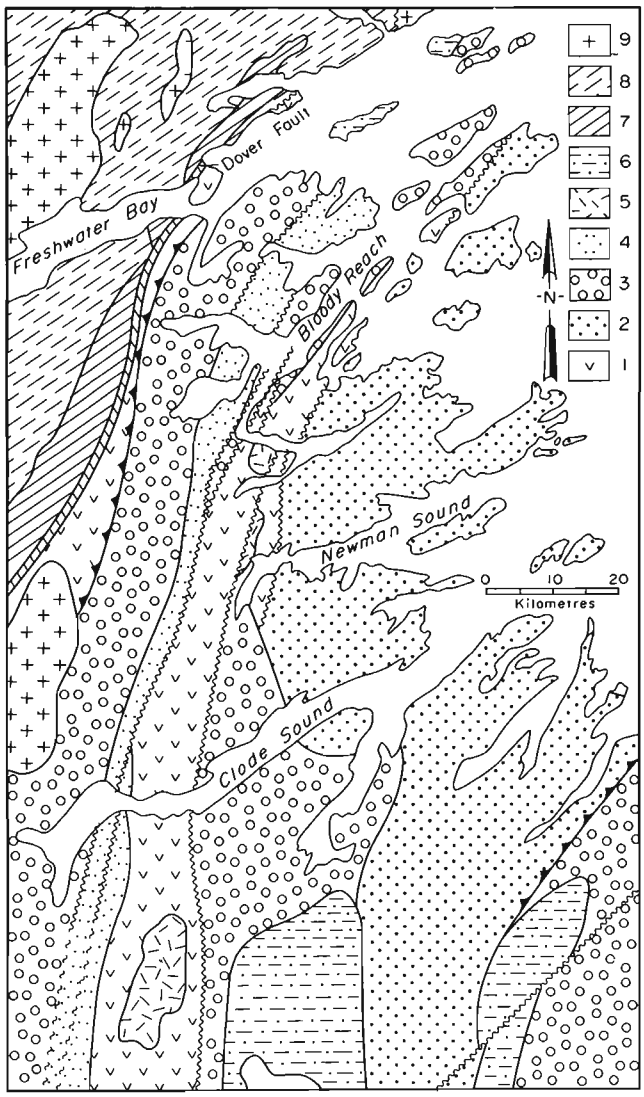

Figure 2: *Geology of the southern and western Bonavista Bay region. 1) Love Cove Group, 2) Connecting Point Group, 3) Musgravetown Group, 4) Thorburn Lake formation, 5) Precambrian granitoids, 6) Cambro-Ordovician rocks, 7) Hare Bay Gneiss, 8) Gander Group and Square Pond Gneiss, 9) Devonian granitoids.*

Alexander Murray described the rocks and mineralization of Bloody Reach and Alexander Bay (Murray and Howley, 1881). Systematic mapping, which outlined the distribution of major units and established some stratigraphic relationships (see below), was carried out by Hayes (1948), Widmer (1949), Christie (1950) and Jenness (1963). More recently, unpublished detailed mapping within portions of the map area was completed by Younce (1970) and Dalbello (1977).

Regional Geological Setting

The Precambrian rocks of southwest Bonavista Bay (Figure 2) are the northernmost exposures of Late Precambrian Avalonian rocks in the Appalachian Orogen. To the west, these rocks are juxtaposed with granite and migmatite along the Dover Fault (Younce, 1970; Blackwood and Kennedy, 1975), a major north–northeast-trending mylonite zone. The Avalonian succession comprises the Love Cove Group (Jenness, 1957), the Connecting Point Group (Hayes, 1948) and the Musgravetown Group (Hayes, 1948). The Love Cove Group, a felsic to mafic volcanic complex, intruded by granites, is exposed in two anticlinoria that are separated by terrestrial sedimentary and volcanic rocks of the Musgravetown Group. The Love Cove Group is, in places, flanked to the east by a thick sequence of marine clastic sedimentary rocks, named the Connecting Point Group. South of Newman Sound, the Love Cove Group is bounded in the east by the Musgravetown Group.

The nature of these groups' contact relationships is enigmatic and controversial. Jenness (1963) considered the Love Cove Group to contain the oldest rocks, and suggested that it unconformably underlies the Connecting Point and Musgravetown groups. Hayes (1948) had previously included these volcanic rocks in the Connecting Point Group, whereas Christie (1950) assigned all volcanic rocks in the Bonavista Bay area to the Musgravetown Group. Younce (1970) disagreed with Jenness (1963), and argued that rocks previously assigned to the Love Cove Group were actually schistose equivalents of the Musgravetown and Connecting Point groups.

Hayes (1948), Christie (1950) and Jenness (1963) all agreed that the Connecting Point Group is separated, at least locally, from the overlying Musgravetown Group by an angular unconformity. Christie (1950), however, suggested that this contact was conformable in the region south of Bonavista Bay, whereas Younce (1970) argued that this contact was everywhere conformable.

Jenness (1963) stated that the contact of the Love Cove and Musgravetown groups is everywhere a fault. Hussey (1979), based on his work in the Port Blandford area to the south, argued that the Musgravetown Group conformably overlies the western belt of the Love Cove Group, thus challenging Jenness's (1963) assertion that the Love Cove Group was deformed prior to the deposition of the Musgravetown and Connecting Point groups. Recently, however, Reusch and O'Driscoll *(this volume)* have re-examined the contacts described by Hussey near Port Blandford, and have suggested that the Love Cove Group–Musgravetown Group contact in that area could be a thrust.

GEOLOGY OF THE EASTPORT AREA, WEST HALF

Introduction

The Eastport area is underlain by Late Precambrian rocks that are disposed in three belts bounded by north-northeast-trending faults (Figure 3). Variably deformed, greenschist-grade, felsic to mafic volcanic rocks, here assigned to the Love Cove Group, are flanked to the west by terrestrial sedimentary and volcanic rocks of the Musgravetown Group, and to the east by marine clastic sedimentary rocks of the Connecting Point Group. A fault juxtaposes the Love Cove Group (whose base is unexposed) with the lowest stratigraphic division of the Connecting Point Group. Near this contact,

tectonic interleaving of both groups has been documented. The Connecting Point Group is overlain with angular discordance by the Musgravetown Group at Clode Sound (Hayes, 1948), three kilometres south of the map area. Along strike to the north, near the Bread Cove Hills, northwest-striking Musgravetown Group rocks truncate the regional northeast strike of the Connecting Point and Love Cove groups. At Northeast Arm, the Love Cove and Musgravetown groups are juxtaposed along a major northeast-trending shear zone. East of this structure, in a faulted syncline, schistose, isoclinally folded Love Cove Group rocks are separated from gently westward-dipping, otherwise undeformed, Musgravetown Group sedimentary rocks by a very narrow exposure gap. This critical contact may represent an unconformity between the Love Cove and Musgravetown groups.

Small bodies of pretectonic granite and quartz diorite intrude the Musgravetown and Love Cove groups. In the vicinity of the Louil Hills, gabbro, diorite, riebeckite granite and hybrid rocks intrude the Love Cove Group. The structural contrast between these rocks and the Love Cove Group suggests they are posttectonic with respect to the main deformation of the group. The Love Cove and Connecting Point groups are also intruded by pretectonic and posttectonic diabase dikes.

Love Cove Group

Variably strained, schistose volcanic rocks of dominantly intermediate to mafic composition, and lesser felsic rocks form a northward-thinning belt that strikes north-northeast across the map area. These rocks form the northern extension of the Late Proterozoic Love Cove Group (Jenness, 1957). In terms of lithology and structural style, they are similar to exposures of the group to the south in the Clode Sound region (Hussey, 1979) and the Burin Peninsula (O'Driscoll, 1977; O'Driscoll and Hussey, 1978; O'Brien *et al.*, 1977; O'Brien and Taylor, 1983; O'Brien *et al.*, 1984). In the Eastport area, the maximum outcrop width of the Love Cove Group varies from 5 km at Southwest Arm to 1 km at Bloody Bay Point.

The Love Cove Group from Bloody Bay Point southward to Northeast Arm is dominated by foliated, mafic to intermediate, chlorite-rich and epidote-rich feldspar-crystal tuff, lithic tuff and tuff-breccia (Plate 1). Rocks of more felsic composition are rare and include highly strained, quartzphyric tuff and sericite–quartz schist. Coarse grained, mafic volcanic breccia and agglomerate are well exposed on the west shore of Long Reach. At Northeast Arm, felsic tuff and breccia display intense flattening, including development of feldspar tails and rotated and flattened lithic clasts. At Long Reach Island, a 500-m-wide belt of felsic tuff, quartz–sericite schist, and silicified tuff and tuff-breccia (subunit 1a) are exposed.

Between Newman Sound and Northeast Arm, the Love Cove Group is divided into a western zone of felsic tuff and breccia, rhyolite, epidote–sericite–quartz schist and siliceous hornfels, and an eastern zone (subunit 1b) of mafic to intermediate tuff, hyaloclastite, pillow lava (Plate 2), pillow breccia, aphanitic mafic rocks and hornfels.

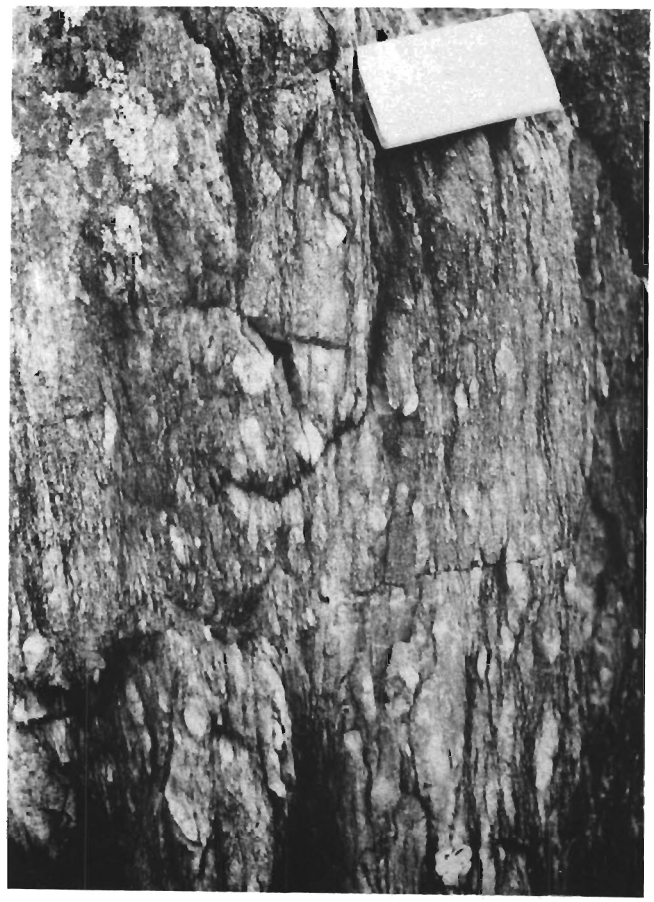

Plate 1: *Flattened lithic tuff-breccia of the Love Cove Group (Unit 1), Northeast Arm.*

Plate 2: *Variolitic pillow lava of the Love Cove Group (subunit 1b), south shore of Newman Sound.*

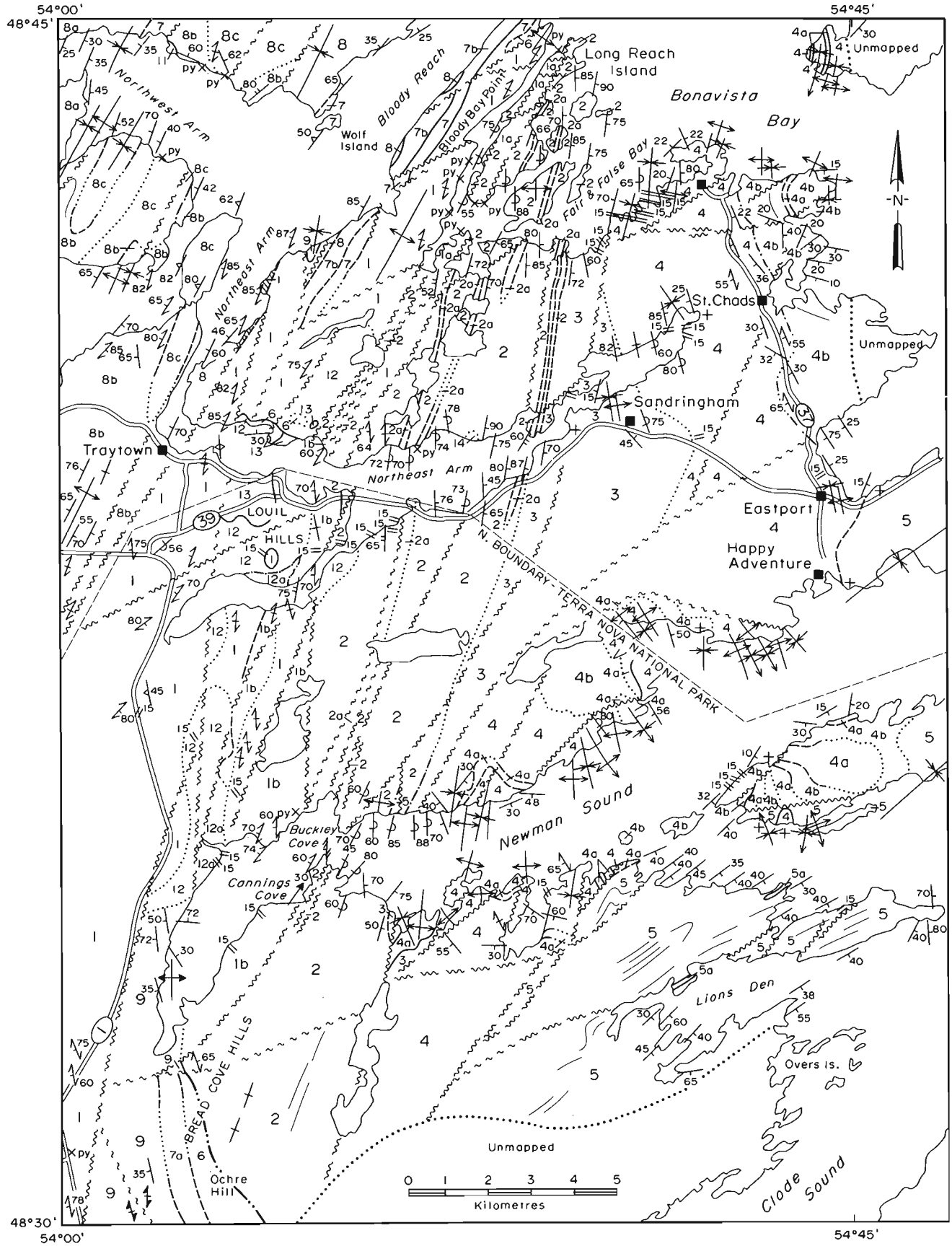

Figure 3. *Geology of the Eastport (2C/12) map area.*

LEGEND

DEVONIAN OR OLDER

15 *Brown, dark-green to black, aphanitic to sparsely porphyritic diabase*

PRECAMBRIAN(?)

LOUIL HILLS INTRUSIVE SUITE (Units 12, 13 and 14)

14 *Medium to coarse grained plagioclase porphyry*

13 *Pink to buff, fine to medium grained, equigranular riebeckite granite*

12 *Fine to medium grained, green and black, equigranular gabbro, diorite, minor diabase and quartz diorite, and agmatite;* 12a, *unseparated gabbro, diorite and hornfels*

PRECAMBRIAN

11 *Gray, medium grained granodiorite and quartz diorite*

10 *Black and white to buff, fine grained, equigranular hornblende–biotite granodiorite*

MUSGRAVETOWN GROUP

9 CROWN HILL FORMATION: *red granule and pebble conglomerate and sandstone, minor green to buff sandstone and pebble conglomerate*

8 ROCKY HARBOUR FORMATION: *cross-bedded and parallel-laminated, green and gray siltstone, sandstone and conglomerate;* 8a, *yellow-green and red, cross-bedded sandstone, siltstone and conglomerate;* 8b, *unseparated felsic tuff, tuffaceous sedimentary rock, quartzite and hornfels;* 8c, *rhyolite flow and rhyolitic tuff*

7 BULL ARM FORMATION: *variegated, flow-banded, autobrecciated, massive and columnar-jointed rhyolite;* 7a, *red ash-flow tuff and rhyolite;* 7b, *green and gray, highly vesicular basalt and basaltic flow-breccia*

6 CANNINGS COVE FORMATION: *red to maroon boulder and pebble conglomerate, buff pebble conglomerate, red sandstone and granule conglomerate*

CONNECTING POINT GROUP

5 *Fine and medium grained, locally quartzose, sandstone interbedded with rare planar-based conglomerate, thin bedded siliceous argillite, thin to medium bedded, rippled sandstone, minor siltstone;* 5a, *massive, felsic tuff bed*

4 *Black slate and shale containing thin lenticular beds and laminae of sandstone;* 4a, *quartzose sandstone and granule to pebble conglomerate;* 4b, *unseparated black shale and minor sandstone*

3 *Thin bedded and planar bedded to laminated black shale and argillite interbedded with sandstone; minor convoluted black shale, locally containing thin discontinuous beds and laminae of sandstone*

2 *Gray tuffaceous sandstone and argillite, black shale containing local vitric tuff laminae, lithic and crystal-lithic tuff, thick and thin bedded (and in places cyclically bedded) graded sandstone and thin shale interbeds, pebbly sandstone and conglomerate;* 2a, *felsic pyroclastic rocks*

LOVE COVE GROUP

1 *Unseparated intermediate and mafic pyroclastic rocks, volcanic breccia, feldsparphyric tuff, volcaniclastic sandstone, minor rhyolite and basaltic tuff, quartz–sericite schist, chlorite–epidote schist and hornfels;* 1a, *rhyolitic and rhyodacitic tuff, tuff-breccia and silicified, rhyolitic volcanic rocks;* 1b, *mafic tuff, agglomerate and breccia, pillow lava, pillow breccia and mafic hyaloclastite, and mafic hornfels*

The base of the Love Cove Group is not exposed in the map area. The Love Cove Group is in fault contact with the main belt of Musgravetown Group near Traytown. Its contact (unexposed) with the Musgravetown Group west and south of Newman Sound is inferred to be a fault. The contact between the groups at Bloody Bay Point could represent an unconformity at the base of the overlying Musgravetown Group. A similar contact (unexposed) may occur near Bluff Head in Northeast Arm. Faulted contacts between the Love Cove and Connecting Point groups are exposed on Long Reach Island and in Newman Sound at Cannings Cove and Buckley Cove.

Connecting Point Group

Marine clastic sedimentary rocks that underlie much of the map area to the east of the Love Cove Group are continuous southeastward, across Chandler Reach, with sedimentary rocks in the type area of the Connecting Point Group (Hayes, 1948). Widmer (1949), Christie (1950) and Jenness (1963) assigned the marine sedimentary rocks in the Eastport map area to the Connecting Point Group. This designation is retained in this study, and a threefold stratigraphic subdivision of the group is erected. Jenness (1963) estimated the maximum thickness of the Connecting Point Group at 9000 m, with approximately 5000 m of section exposed in the Eastport map area.

The basal division of the Connecting Point Group (Unit 2) is a 4-km-wide belt of vertical to west-dipping overturned strata, extending from Fair and False Bay south-southwestward to the Bread Cove Hills, where it is truncated by rocks of the Musgravetown Group. Unit 2 is a coarsening- and thickening-upward clastic sequence containing interbedded felsic tuff bands (subunit 2a); at least 2200 m of this section is exposed on the islands of Fair and False Bay (I. Knight, personal communication, 1986). Up to 500 m above its base, the sequence is characterized by gray, siliceous, slumped and laminated tuff (Plate 3), lithic tuff, and black shale interbedded with graded tuffaceous sandstone and siliceous siltstone. These rocks are succeeded by tuffaceous sandstone, with a relatively higher proportion of interbedded black shale and cherty argillite, overlain in turn by turbidite-facies bedded sandstone and shale (Plate 4). The upper third of Unit 2 is dominated by thick bedded, coarse grained sandstone and pebbly sandstone containing intraformational conglomerate scours (Plate 5).

Unit 2 is overlain and succeeded eastward by thin, parallel and planar bedded black shale and siltstone, and rare interbedded sandstone (Unit 3), and more extensive black shale containing distinctive 1 to 2 cm lenticular interbeds of fine grained sandstone (Unit 4). Thickness estimates are hampered by numerous faults and folds within the succession. Unit 4 also contains regionally mappable subdivisions, several tens of metres thick, of coarser grained clastic rocks, designated as subunit 4a on Figure 3. These rocks consist of massive to cross-stratified, normally and inversely graded sandstone, together with locally imbricated, matrix-supported, pebble and granule conglomerate, and beds of brown, quartzose sandstone. The basal contacts of subunit 4a with the enclosing shale succession is gradational, and is marked by an abrupt increase in the thickness of sandy interbeds within the shale.

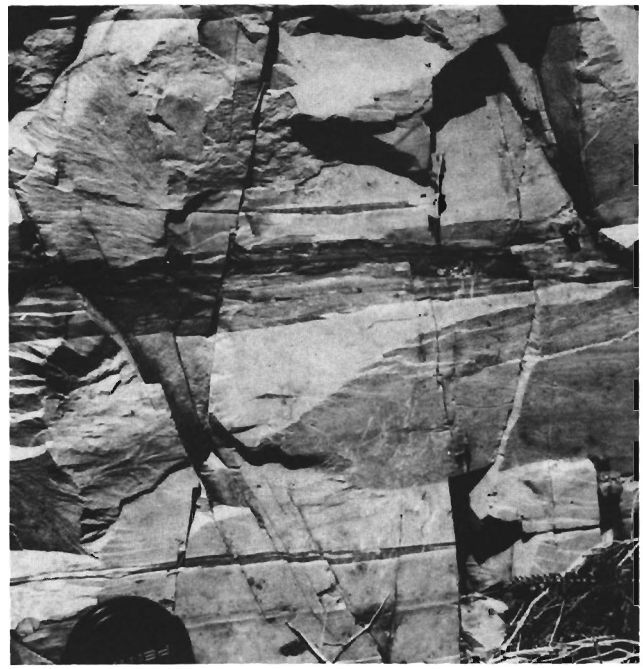

Plate 3: *Dark-gray, slumped and finely laminated vitric tuff interbeds in siliceous siltstone, near base of the Connecting Point Group (Unit 2), Long Reach Island.*

Plate 4: *Graded, fine grained sandstone turbidites interbedded with shale, Connecting Point Group (Unit 2), Fair and False Bay.*

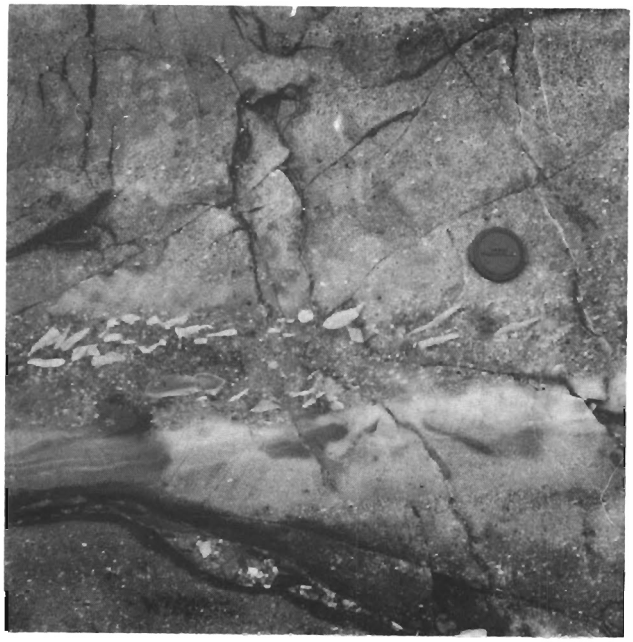

Plate 5: *Interbedded, massive to crudely stratified sandstone and cross-laminated siltstone of the Connecting Point Group (Unit 2), island in Fair and False Bay; note siltstone rip-ups incorporated in base of the massive sandstone.*

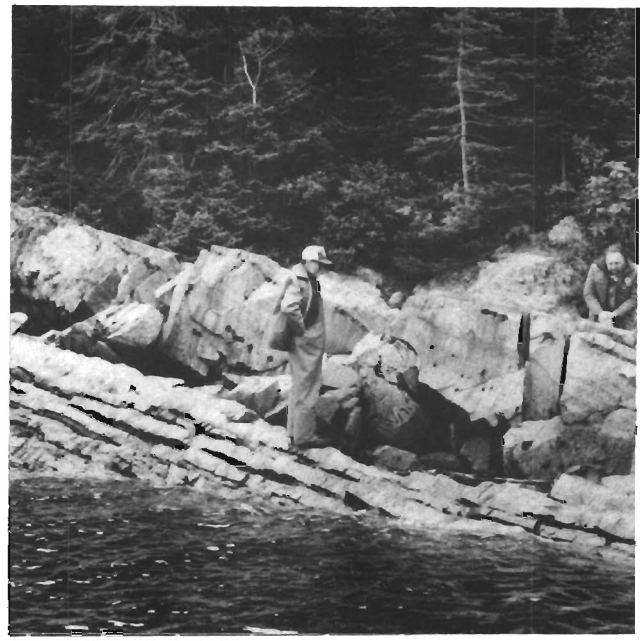

Plate 6: *Planar-based conglomerate scouring a coarsening-upward, thin bedded sandstone sequence, Connecting Point Group (Unit 5), south shore of Newman Sound, near Swale Island.*

At Eastport, and also on the south shore of Newman Sound, Unit 4 shale is gradationally overlain by approximately 3000 m of sandstone and siltstone (Unit 5). These rocks are best exposed along the shore south of Swale Island and in the Lions Den (Figure 3), where they occupy a gently to moderately southeast-dipping homocline. Three major sandstone units, the largest of which is over 200 m thick, are intercalated with Unit 4 shale immediately below the basal sandstone of Unit 5. The lower part of Unit 5 is dominated by quartz-rich sandstone in 10- to 30-cm-thick amalgamated beds with thin, discrete interbeds of shale. These rocks are succeeded by thin bedded sandstone containing rare planar-based sandstone and conglomerate scours, up to 3 m thick (Plate 6). The middle part of the succession is characterized by cyclic sequences of thin bedded, very siliceous siltstone, overlain by thin to medium bedded sandstone. The latter is scoured by much thicker amalgamated sandstone beds. A cycle is capped by thin bedded sandstone. The upper part of the sequence on the north shore of the Lions Den is dominated by thin and thick bedded sandstone turbidites and rippled sandstone. As much as 2000 m of stratigraphically higher Connecting Point Group strata are exposed within the map area at Overs Island and Clode Sound.

The contact of the Connecting Point Group with the main belt of Love Cove Group is not exposed in the Bloody Bay Point area; the contact in Newman Sound is a fault. At Long Reach Island, a 200-m-wide belt of overturned, basal Connecting Point Group sedimentary rocks (Unit 2) separates the main belt of Love Cove Group rocks from equivalent volcanic rocks. The western contact between the volcanic rocks on Long Reach Island and the Connecting Point Group is a several-metre-wide zone of brecciation and shearing. In contrast, the eastern contact of those units is a sharp discordance, such that bedding in the basal Connecting Point Group strikes at a low angle into Love Cove Group rhyolite tuff to the west. Because of the discordance of bedding, the contact is interpreted as a fault. It is important to emphasize that the sedimentary rocks at this contact form the stratigraphically lowest part of the Connecting Point Group in the map area. The significant proportion of volcanic rocks and tuffaceous sedimentary rocks in the basal division of the Connecting Point Group suggests that any hiatus that may be represented by the Connecting Point–Love Cove group contact is neither extensive nor significant, and that their contact is possibly conformable.

Musgravetown Group

Terrestrial and marine clastic sedimentary and volcanic rocks, here included in the Musgravetown Group, are exposed in the northwest and southwest parts of the map area. The westward-younging succession in the Ochre Hill–Bread Cove Hills area is continuous southward, across Clode Sound, to the type area of the Musgravetown Group (Hayes, 1948). A condensed sequence of essentially similar rock types on the east shore of Bloody Reach, west of the Love Cove Group, forms the northern extension of this belt. The sedimentary and volcanic rocks exposed west of the Bloody Reach fault were originally designated as Love Cove Group by Jenness (1963). These rocks were subsequently reassigned to the Musgravetown Group by Younce (1970), who demonstrated that the succession conformably underlies the uppermost part of the Musgravetown Group, which passes, in turn, conformably upward into Lower Cambrian Random Formation. The original formational nomenclature of Jenness (1963) is

retained to designate the Musgravetown Group succession of the map area. From base to top, the formations are the Cannings Cove, Bull Arm, Rocky Harbour and Crown Hill.

The *Cannings Cove Formation* (Unit 6) is exposed only east of the Bloody Reach fault. It is progressively finer grained from south to north across the map area. At Ochre Hill, the formation consists of red and maroon, granule, pebble and boulder conglomerate, and a minor proportion of red sandstone. The conglomerate is massive and mostly clast supported. Clasts, which are either subangular or rounded, consist of red feldsparphyric and aphyric rhyolite, welded tuff, felsite, rhyolite porphyry, shale, green siltstone, sandstone and fine grained basalt. South of the map area at Clode Sound, the conglomerate contains a significant proportion of sericite-schist clasts (Hussey, 1979). At Northeast Arm, 2 km north of Louil Hills, thermally metamorphosed conglomerate of the Cannings Cove Formation occurs mainly as a small roof pendant in granite. The conglomerate is gray to green, and is mostly massive, exhibiting rare, large-scale cross-beds. Clasts are rounded and include mostly gray rhyolite and welded tuff, diabase, porphyritic diabase, gabbro, quartz, and rare orange granite. At Bloody Bay Point, the Cannings Cove Formation consists of less than 100 m of thick bedded, coarse grained red sandstone and granule conglomerate.

At Clode Sound, approximately 3 km south of the map area, the Cannings Cove Formation unconformably overlies deformed Connecting Point Group rocks (Hayes, 1948) (Plate 7). There, basal Cannings Cove conglomerate contains cobbles of sericite schist (Hussey, 1979) as well as a variety of sedimentary and volcanic clasts. The unconformity strikes northward to Ochre Hill, but it is not exposed at that locality. At Bloody Bay Point, a 2-m-wide exposure gap separates basal Cannings Cove Formation from schistose, isoclinally folded, quartzphyric rhyolite tuff of the Love Cove Group. There, the Cannings Cove Formation is gently dipping and relatively unmetamorphosed; basal sandstone contains no tectonic fabric and is neither fractured nor brecciated. This contact may represent an unconformity between the Love Cove and Musgravetown groups (cf. Jenness, 1963; see below).

Volcanic rocks of the *Bull Arm Formation* (Unit 7) overlie the Cannings Cove Formation at Ochre Hill and Bloody Bay Point. West of the Bloody Reach fault, rhyolitic volcanic rocks that occur disconformably below the Rocky Harbour Formation at Wolf Island are assigned to the Bull Arm Formation. At Bloody Bay Point, red sandstone and pebble conglomerate of the Cannings Cove Formation is overlain by a vesicular basalt flow, which is succeeded by over 100 m of finely banded to massive rhyolite flows. The rhyolite unit is overlain by vesicular basalt capped by a red sandstone bed, which is overlain by several thick flows of vesicular basalt. At Wolf Island, the Bull Arm Formation consists of rhyolitic volcanic breccia, succeeded by massive to columnar-jointed rhyolite, which is overlain by intricately flow-banded rhyolite.

The base of the Bull Arm Formation is conformable with the Cannings Cove Formation at Bloody Bay Point, where the basal basaltic flow is in sharp contact with underlying red sandstone of the Cannings Cove Formation. South of Ochre Hill at Clode Sound, Hussey (1979) has described the contact of these formations as conformable.

Plate 7: *Unconformable contact of Musgravetown Group and underlying Connecting Point Group, Clode Sound; hammer placed at surface of angular unconformity.*

The *Rocky Harbour Formation* (Unit 8), (Jenness, 1963) is the major stratigraphic unit exposed west of the Bloody Reach fault, where it consists mainly of green cross-bedded sandstone and conglomerate. Rhyolite flows and tuff exposed in the Northwest Arm region are tentatively included with this formation. East of the Bloody Reach fault, the Rocky Harbour Formation is represented by several tens of metres of green siltstone and sandstone, which intervene between the upper basaltic flow of the Bull Arm Formation and the basal red conglomerate of the Crown Hill Formation on the east shore of Bloody Reach. On his unpublished map, Younce (1970) shows a very thin band of Rocky Harbour Formation overlying the Bull Arm Formation at Ochre Hill; the occurrence of this band was not confirmed during this study.

On the accompanying map (Figure 3), the Rocky Harbour Formation is subdivided into one unit and three subunits. Unit 8 consists mainly of green, yellow-green and gray-green, parallel-stratified and cross-stratified sandstone, siltstone and tuffaceous graywacke, including pebble-conglomerate channels (Plate 8). Unit 8 hornfels is exposed on both shores of Northwest Arm. The western exposures of the Rocky Harbour Formation are typically cross-stratified yellow-green sandstone (subunit 8a). Planar and lenticular bedded variants are less abundant within this unit. The green sandstone contains planar and lenticular interbeds of both red and purple sandstone, and locally, detrital magnetite occurs in foresets of small-scale crossbeds. Subunit 8b consists of intercalated felsic tuff and thinly banded tuffaceous sedimentary rocks, containing interbeds of white to buff quartzitic sandstone. Subunit 8c consists of felsic volcanic rocks, mainly rhyolite and ash-flow tuff, that form thick, compound flows within subunit 8b.

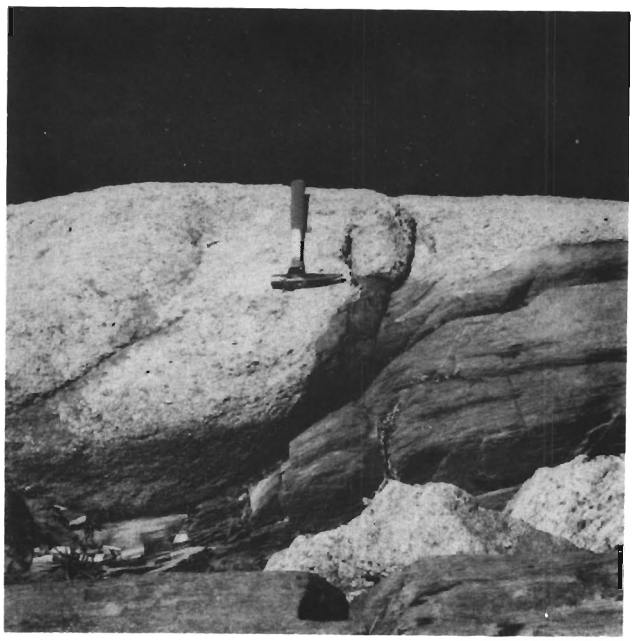

Plate 8: *Channelled, pebble conglomerate eroded into planar-stratified green sandstone, Rocky Harbour Formation, Musgravetown Group, Northwest Arm.*

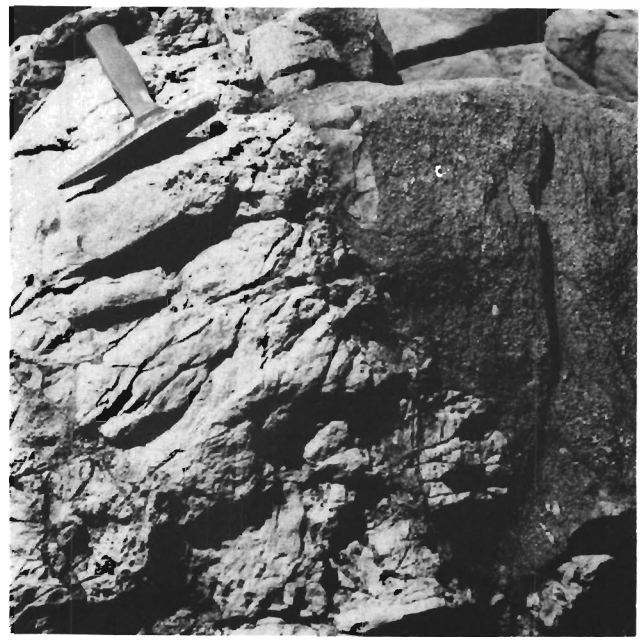

Plate 9: *Erosional contact between overlying Rocky Harbour Formation sandstone and conglomerate, and rhyolite of the Bull Arm Formation, Northwest Arm near Wolf Island.*

The Rocky Harbour Formation disconformably overlies the Bull Arm Formation on Wolf Island. Granule conglomerate contains rare, rounded boulders of adjacent, underlying Bull Arm Formation rhyolite (Plate 9). On the east shore of Bloody Reach, the contact of the Rocky Harbour Formation with the Bull Arm Formation is sharp and concordant.

Red sandstone and conglomerate of the *Crown Hill Formation* form the highest part of the Musgravetown Group succession exposed in the Ochre Hill belt and on the east shore of Bloody Reach. In the former area, the formation comprises openly folded and cleaved, massive to thin and medium bedded, red-maroon and bright-red sandstone and shale, pebble and granule conglomerate, and pebbly sandstone. The conglomerate beds fine upward into red sandstone followed by red shale. Rip-up clasts of red shale occur in the overlying conglomerate bed. At Bloody Reach, bright-red pebble and cobble conglomerate of the Crown Hill Formation occupies the core of a north-plunging syncline.

The Crown Hill Formation conformably overlies a condensed succession of Rocky Harbour Formation sandstone along the east shore of Bloody Reach. At Ochre Hill, the Rocky Harbour Formation has not been defined, and the Crown Hill Formation is inferred to directly overlie the Bull Arm Formation. The absence of Rocky Harbour Formation sandstone implies that either the entire formation has been tectonically removed or the contact is a regional disconformity.

Pretectonic Granitoid Plugs

A buff to black and white, fine grained, equigranular, hornblende–biotite granodiorite containing aphanitic mafic xenoliths is exposed on the west shore of Long Reach Island. The small intrusive body, designated as Unit 10, is in fault contact with a thin belt of basal Connecting Point Group rocks, and is inferred to be intrusive into the Love Cove Group.

A small body of gray, medium to coarse grained, weakly foliated quartz diorite and granodiorite (Unit 11) is exposed for several hundred square metres on the north shore of Northwest Arm. Unit 11 is intrusive pretectonically into subunit 8b of the Musgravetown Group, and is surrounded by an extensive hornfels zone containing characteristic deformed epidote nodules.

Louil Hills Intrusive Suite

In the east-central part of the map area, an elongate, north-northeast-trending suite of diorite, gabbro and alkaline granite intrudes the Love Cove and Musgravetown groups. These rocks were referred to previously as the Louil Hills granite (Jenness, 1958). A new name, Louil Hills intrusive suite, is informally proposed here to designate these rocks. This name properly reflects the lithological diversity of these rocks and is in keeping with the recommendations of the Code of Stratigraphic Nomenclature.

Unit 12, the most extensive phase, consists of fine to medium grained, green and black, equigranular pyroxene gabbro and diorite, intruded by diabase and other aphanitic basic dikes. Near the margins of the intrusive suite at Northeast and Southwest arms and at Newman Sound, agmatite, quartz diorite and acidic–basic hybrid rocks are exposed. The mafic rocks of Unit 12 contain variably sized xenoliths of Love Cove Group volcanic rocks. Zones rich in these xenoliths are designated subunit 12a on Figure 3.

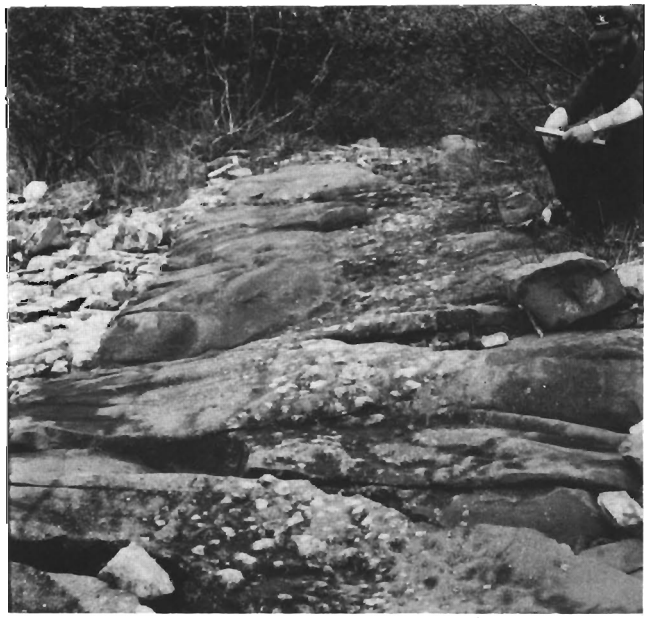

Plate 10: *Zoned mafic dike showing a glomeroporphyritic core, Northeast Arm.*

The granite phase (Unit 13) of the suite forms a roughly circular intrusion cored by the large ring-shaped outcrop that forms the Louil Hills. The granite is pale orange, buff and locally pale red-purple. It is equigranular, quartz rich, fine grained (1 to 3 mm), riebeckite bearing and leucocratic. On the south shore of Northeast Arm it contains quartz phenocrysts and 1-cm myrmekitic patches. On the north shore of the arm, near the contact with the Musgravetown Group, the granite is coarsely miarolitic. The granite intrudes gabbro of Unit 12 and is itself cut by several pink granite aplite veins and at least one diabase dike.

Dikes and small plugs of coarse grained, plagioclase–pyroxene porphyry (Unit 14) intrude the gabbro–diorite phase of the complex, as well as the Connecting Point and Love Cove groups. Some of these dikes are zoned, exhibiting composite, intermediate to basic, aphanitic margins, and cores rich in plagioclase aggregates whose size increases toward the dike core (Plate 10).

The Louil Hills intrusive suite intrudes the three groups of the map area. Although its contact with the Love Cove Group is unexposed, structural contrasts between rocks from both sides of the contact suggest that the suite intruded posttectonically with respect to the main foliation in the Love Cove Group. Similarly, zoned dikes of Unit 14 intrude the Connecting Point Group posttectonically. Direct evidence for the structural relationship between the Louil Hills intrusive suite and the Musgravetown Group is lacking.

The age of the Louil Hills intrusive suite is unknown. The suite is lithologically and compositionally similar to, and is here correlated with, the Cross Hills Intrusive Suite of the Burin Peninsula (O'Brien *et al.*, 1984), which is Late Precambrian–Early Cambrian (G. Dunning, personal communication, 1987). However, a middle Paleozoic age, similar to that of the alkaline St. Lawrence Granite (Strong *et al.*, 1978), cannot be refuted without geochronological data.

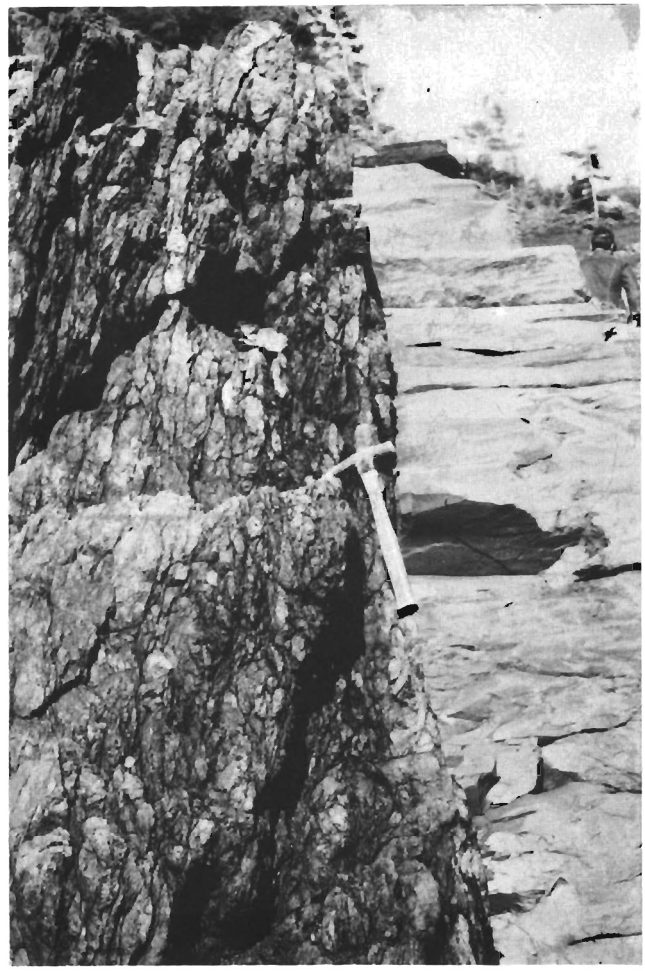

Plate 11. *Sheared intermediate breccia of the Love Cove Group intruded by posttectonic diabase dike.*

Dikes

Pretectonic and posttectonic dikes, mainly of mafic composition, intrude all map units. The dikes are more widespread in the Connecting Point Group than in the Love Cove Group, and occur only rarely in the Musgravetown Group. At least two general sets of dike orientation occur.

Steeply dipping to vertical, foliated and chloritized metabasic dikes having north-northwest to east-northeast trends are most common within the Love Cove Group. They are of variable width, but rarely exceed 1 m. Pretectonic rhyolite and felsite dikes are present, but are relatively rare. Massive, posttectonic, brown-weathering, aphyric diabase dikes (Plate 11) are rare and have general east–west orientations. Neither crosscutting nor composite dikes were noted in the Love Cove Group.

The Connecting Point Group hosts both pretectonic and posttectonic diabase dikes, as well as late porphyry dikes and plugs related to the Louil Hills intrusive suite. Dikes are common in Units 2, 3 and 4 of the group, but are rare in Unit

5. The most widespread and common dikes are posttectonic, roughly east-trending, brown-weathering, aphanitic, very fine grained, vesicular or sparsely plagiophyric diabase. Pretectonic diabase dikes are concentrated near the eastern contact of Unit 6.

Dikes are absent from Musgravetown Group rocks east of the Bloody Reach fault. However, rare, northeast-trending, posttectonic, brown-weathering diabase dikes intrude the Musgravetown Group rhyolites (subunit 8c) at Northwest Arm.

The age of the mafic dikes is unknown. The north-trending dikes in the Love Cove Group predate the formation of the steep foliation in the host volcanic rocks, the age of which is not certain, but previously considered to be Devonian (Dallmeyer *et al.*, 1983). The east-trending posttectonic dikes crosscut regional foliations in the Love Cove and Connecting Point groups, but were not observed in the Musgravetown Group. The dikes may be as young as, and genetically related to, lithologically similar, post-Devonian dikes that intrude rocks immediately west of the Dover Fault (see Jayasinghe, 1978).

Structure

The disposition of stratified rocks within much of the map area is controlled mainly by an asymmetrical, tight anticlinorium–open synclinorium pair. Parasitic folds and major and minor north-northeast-trending and east-northeast-trending faults also control the distribution of units. The largest intrusion in the area, although posttectonic, is elongated parallel to the north-northeast-trending regional structural grain, and may be sited on or near an ancestral fault.

The Love Cove Group is interpreted to occupy the core of a north-northeast-trending, overturned, north-plunging anticlinorium whose axial plane dips west. This structure is truncated westward by a major, north-northeast-trending shear zone, named the Bloody Reach fault. Small-scale isoclinal folds within the Love Cove Group are locally exposed. The dominant structure of the Love Cove Group is a strong, vertical to steep, west-dipping penetrative foliation. The relationship of this fabric to regional folding has yet to be established. The Love Cove Group is cut by numerous north-northeast-trending faults. Its western contact, the Bloody Reach fault, is a major high-strain zone that may be the site of significant vertical throw and transcurrent movement. Its eastern contact with the Connecting Point Group varies from a wide shear zone modified by later brittle faulting (e.g., Newman Sound), to the sharp discordance exposed at Long Reach Island.

The contact of the Love Cove Group with the Connecting Point Group is disposed on the eastern limb of the anticlinorium, striking north-northeastward through Bloody Bay Point. The basal Connecting Point succession (Unit 2) lies adjacent to the Love Cove Group on the overturned eastern limb of the anticlinorium. Almost the entire basal kilometre of section is eastward younging, vertical to west-dipping, and therefore overturned. Minor east-verging parasitic folds result in younging reversals on both structures. In general, the regional dip of the succession, together with fold amplitudes, decreases eastward. The contact of Unit 2 with less competent overlying shale of Unit 3 is faulted locally; elsewhere it is moderately dipping and upright. The structural style of much of Units 3 and 4 of the Connecting Point Group is characterized by numerous small-amplitude, east-verging, inclined folds, and upright folds, best developed in the shaley facies. The distribution of the sandstone and conglomerate members (subunit 4a) is controlled by south-plunging synclines and shallowly plunging periclines that have curvilinear hinge lines and steep axial surfaces. Enclosing shales are highly folded and display a strong slatey cleavage; folds trend between 300 and 000. Within the map area, much of the upper part of the Connecting Point Group occupies an east-dipping homocline, interrupted by rare minor folds. Both the Love Cove Group and the Connecting Point Group are cut by late east-northeast-trending faults.

The Ochre Hill belt of Musgravetown Group rocks overlies the Connecting Point Group unconformably (Hayes, 1948). At Clode Sound, Connecting Point Group sedimentary rocks are deformed by tight asymmetrical folds and an associated axial planar slatey cleavage, whereas the overlying Musgravetown Group, which contains none of the D_1 structures of the Connecting Point Group, is disposed in a west-dipping homocline (Hussey, 1979). Northward, however, adjacent to the fault contact with the Love Cove Group, the Musgravetown Group is deformed about north-trending fold axes. The Musgravetown Group rocks that outcrop between the Love Cove Group and the Bloody Reach fault also dip westward off the Love Cove Group, and occupy the east limb of a north-plunging syncline.

West of the Bloody Reach fault, the Musgravetown Group is deformed by regional, north-northeast-trending, mainly north-plunging folds. Variably intense axial planar cleavage is developed widely. In the northwest corner of the map area, stratigraphically above the westernmost exposure of Bull Arm Formation, sedimentary rocks are disposed in a broad, open syncline. There is a general westward decrease in fold amplitude in Musgravetown Group rocks west of the Bloody Reach fault within the map area.

Metamorphism

Rocks within the map area contain mineral assemblages diagnostic of low-grade regional metamorphism. The Love Cove Group typically contains quartz–epidote–sericite and chlorite–epidote–albite assemblages. Similar chlorite-grade assemblages are developed locally in tuff of the Connecting Point Group. Prehnite was noted only in the Ochre Hill belt of the Musgravetown Group. Thermal metamorphic aureoles surround the Louil Hills intrusive suite and Unit 11 granite.

Time of deformation

Unequivocal contact relationships that can provide constraints on timing of deformation and associated metamorphism are lacking within the present map area. Several important observations, which have a bearing on the age of deformation, have been made in adjacent map areas. These are:

1) the angular unconformity between the Connecting Point Group and the overlying Musgravetown Group (Hayes, 1948)

2) the folded nature of that contact (Jenness, 1963)

3) the folded, conformable contacts between the Rocky Harbour, Crown Hill and Lower Cambrian Random formations in the Reach syncline (Younce, 1970)

4) the faulted nature of all Love Cove Group–Musgravetown Group contacts

5) the local presence of foliated metamorphic detritus (cataclastic granite, foliated volcanic and sedimentary rocks, sericite schist, sericite) in Musgravetown Group rocks from several areas of the western Avalon Zone (Jenness, 1963; Williams, 1971; Hussey, 1979; O'Brien and Taylor, 1983)

6) an unpublished, Late Precambrian U–Pb zircon age on Bull Arm Formation rhyolites above the unconformity in Clode Sound (Newfoundland Department of Mines and Energy, 1980).

The first three relationships together establish that, within the region, there exists two episodes of deformation–one pre-Musgravetown Group, one post-Random Formation. The fourth observation permits the possibility that the Love Cove Group records both Paleozoic and Precambrian deformations. The fifth point suggests that Precambrian deformation was not restricted to pre-Musgravetown Group rocks of the Bonavista Bay area. The final point indicates that the pre-Musgravetown Group deformation was of Precambrian age.

The marked structural contrast between Musgravetown and Love Cove group rocks that are juxtaposed on Bloody Bay Point, coupled with the almost total lack of tectonic structure within lowermost Musgravetown Group strata, may indicate that the foliation in the Love Cove Group at that locality predates the Musgravetown Group and is of Precambrian age. That interpretation would provide an explanation for the west-dipping and westward-younging nature of basal Musgravetown Group strata observed in contact with the Love Cove Group on both sides of the anticlinorium occupied by Love Cove Group rocks. The regional folds of Musgravetown Group rocks west of the Bloody Reach fault deform Lower Cambrian Random Formation quartzite (Younce, 1970), and are thus Paleozoic.

The degree and extent of pre-Musgravetown Group deformation is uncertain. $^{40}Ar/^{39}Ar$ geochronology of whole-rock phyllites from west and south of the map area has been used to argue that much of the metamorphism of the region occurred between 388 Ma and 353 Ma, and is therefore of Acadian age (Dallmeyer *et al.*, 1983). However, structural contrasts suggest, and unconformities prove, that at least some Precambrian structures exist within the Love Cove and Connecting Point groups. The Precambrian deformation may be restricted to local faults or relatively narrow shear zones; however, the existence of pre-Musgravetown Group metamorphic detritus elsewhere within the Avalon Zone indicates more widespread effects of this tectonism.

ECONOMIC GEOLOGY

The Love Cove Group is host to numerous pyrite occurrences and silicified zones on Long Reach Island, and along the west shore of Long Reach and on the mainland to the south. At the south end of Long Reach Island, several pyritic gossans, and silicified and sericitized zones are exposed within a fault-bounded belt, 600 m wide, of rhyolitic volcanic rocks. The two largest silicified zones are approximately 200 m and 30 m wide, although much narrower zones occur across this belt. The altered rocks are white to gray-green, sheared, quartzphyric, lithic tuff breccia, fine grained lithic tuff, and more massive cherty rhyolite. These rocks are spatially associated with locally siiicified agglomerate and volcanic breccia. The altered rocks are cut by pretectonic veins, 1 to 10 cm wide, of dark gray quartz, and by posttectonic diabase dikes. Visible sulfide mineralization is in the form of very fine to fine grained, variably disseminated pyrite. Samples of silicified, pyritized rhyolite have yielded consistently, albeit only slightly, elevated gold values up to 110 ppb Au (Neutron Activation Analyses by Chemex Labs). Silicified and sericitized rhyolitic volcanic rocks occur along strike at least 4 km to the north and approximately 1 km to the south. Minor disseminated pyrite occurs in mildly silicified rhyolite tuff and breccia that are juxtaposed with pyritiferous slate of the Connecting Point Group, approximately 6 km along strike at Northeast Arm. Farther south, a pyritic gossan within intermediate volcanic rocks of the Love Cove Group is exposed on the north shore of Newman Sound, approximately 1 km west of Buckley Cove, in Terra Nova National Park. In the southwestern corner of the map area, highly strained, pyrite-rich rhyolite and rusty sericite schist of the Love Cove Group is exposed in road cuts along Route 1. Extensive pyritic gosssan is developed along much of the western shoreline of Long Reach, northward for almost 2 km from Mishes Cove. Mineralization consists of finely disseminated pyrite in foliated and locally silicified, pale-green plagiophyric tuff and mafic volcanic breccia. On the southeast shore of the harbour west of Mishes Cove, pyritized felsic volcanic rocks are juxtaposed with pyrite-rich black shale that is overlain by silicic breccia, fine grained metabasic rocks, and tuffaceous argillite of the basal Connecting Point Group.

Pyritiferous shale and slate are widespread in the lowermost stratigraphic levels of the Connecting Point Group. Volcanic rocks (subunits 8b and 8c) of the Musgravetown Group are host to small pyrite occurrences around Alexander Bay. Mineralization occurs in black glassy rhyolite intercalated with thin bedded tuffaceous sedimentary rocks, and also in rhyolite dikes that cut sandstones of Unit 8.

In terms of mineral potential, all map units must be considered as important regional target areas. The Love Cove Group contains zones of silicified and altered rocks in proximity to major faults. These zones should be sampled in detail for gold mineralization. The extent of known alteration zones and the possible existence of other, undiscovered zones should be investigated. The known alteration zones lie near the top of the Love Cove Group, and, like the Hickeys Pond Belt to the south (Huard and O'Driscoll, 1986), are localized at its eastern margin. In terms of both rock types and

general intrusive history, the Love Cove Group and adjacent rocks resemble some of the auriferous units of the Hermitage Flexure in the Dunnage Zone (O'Brien *et al.*, 1986), and a similar scale of mineralizing events in the Precambrian rocks should be anticipated.

The Connecting Point Group is similar in lithology, metamorphic history and, in part, structural style to the Meguma Group of southern Nova Scotia, an important host to numerous occurrences of gold in quartz veins (Fairbault, 1889; Graves and Zentilli, 1982). The gold-bearing veins there are related either to metamorphic fluids (Crocket *et al.*, 1986), to intrabasinal fluids derived from metalliferous horizons in the Meguma Group (Graves and Zentilli, 1982), or to magmatic hydrothermal fluids related to granite intrusion (Smith, 1983). These hypotheses may be applicable to the Connecting Point Group, particularly north of the Eastport area, where the group is intruded by numerous bodies of diorite and gabbro. The auriferous arsenopyrite–quartz veins that occur at the contact of diorite and Connecting Point Group shale about 15 km north of the map area at Gooseberry Island (Murray and Howley, 1881) may indicate that such processes have been active in this region.

Volcanic rocks of the Musgravetown Group, like those of the Love Cove Group, are mineralized and display some evidence of alteration. In the type area of the Bull Arm Formation at the Isthmus of Avalon, the volcanic rocks have undergone very widespread and pervasive potassic metasomatism (Hughes and Malpas, 1971). Such alteration is a significant indication of the type of hydrothermal activity that is favourable for epithermal gold mineralization. It is possible that similar metasomatism is common throughout the entire Musgravetown Group volcanic field.

Finally, the Louil Hills intrusive suite, by nature of its composition and peralkaline chemical affinity (unpublished data), is a potential host of rare-earth-element mineralization, analagous to that in the lithologically similar Cross Hills Intrusive Suite of the Terrenceville area to the south (O'Brien *et al.*, 1984). It is also similar to Late Precambrian peralkaline complexes of the Afro-Arabian Pan-African belts (Drysdale *et al.*, 1984) that host small, high-grade deposits of rare-earth elements.

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