Current Research (2012) Newfoundland and Labrador Department of Natural Resources
Geological Survey, Report 12-1, pages 121-145

GEOLOGY OF THE RANDOM ISLAND MAP AREA (NTS 2C/04), NEWFOUNDLAND

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ABSTRACT

The Random Island map area (NTS 2C/04) was mapped at 1:50 000 during the 2011 field season. This study built on previous work and now provides a more detailed delineation of Late Neoproterozoic to Early Ordovician development of the western Avalon Zone. Superbly exposed cross-sections of volcanic and coeval plutonic rocks and related sedimentary rocks represent volcanic arc and arc-adjacent basin infill environments.

The diverse geology of the Random Island map area is subdivided into three Neoproterozoic groups (Love Cove, Connecting Point, and Musgravetown); two Neoproterozoic granitic bodies (Swift Current and Clarenville), and three post-Cambrian sedimentary units (Random Formation, and the Adeyton and Harcourt groups). The oldest rocks in the map area are the Late Neoproterozoic Love Cove Group sericite–chlorite schists, and associated meta-sedimentary and aphanitic andesitic volcanic rocks. These rocks are exposed in a 3-km-wide north–south-striking belt on the western margin of the map and act as basement for the overlying sedimentary and volcanic rocks; the belt is intruded by two separate but lithologically similar granitic plutons, namely the Swift Current and the Clarenville granites. Neoproterozoic sedimentary and volcanic rocks of the Connecting Point and Musgravetown groups dominate the central and eastern portions of the map area, which are, in turn, overlain by three post-Cambrian subbasins of clastic and minor carbonate rocks.

INTRODUCTION

Detailed bedrock mapping of the Random Island map area (NTS 2C/04) was completed during the 2011 summer field season. This report summarizes the initial findings of a new, 1:50 000-scale mapping project on Random Island, and a continuation of geological mapping on the west side of Trinity Bay (Normore, 2010, 2011). Field work concentrated on the mapping and subdivision of the Connecting Point, Musgravetown, Adeyton, and Harcourt groups, with an emphasis on determining the potential for sediment-hosted copper occurrences in the upper Musgravetown Group.

LOCATION, ACCESS AND PHYSIOGRAPHY

Random Island is located on the west coast of Trinity Bay and is the second largest island off the coast of Newfoundland (Figure 1). The map area lies within the tectonostratigraphic Avalon Zone of Williams (1979). Clarenville is the largest town and commercial hub, located immediately east of the Trans-Canada Highway that runs north–south through the western part of the map area; a deeply embayed

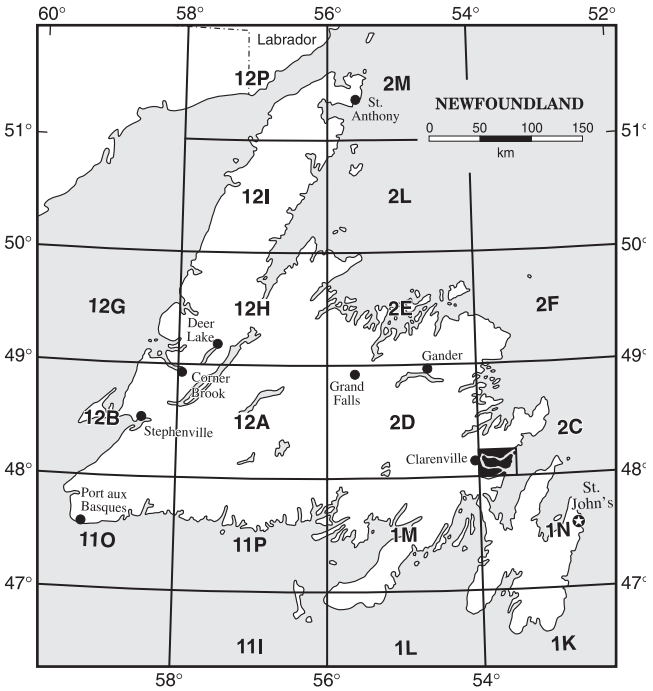

Figure 1. *Location map of the study area (NTS 2C/04).*

coastline is the dominant physiographic feature. Smith Sound, Northwest Arm and Southwest Arm fiords cross east–west through the entire map area from north to south. The extensive coastal exposures were surveyed using a 19-foot open-boat, while the interior was accessed primarily *via* foot, but also with limited helicopter support. Access is obtained through a network of paved roads, two resource roads (Lady Cove and Burgoyne's Cove resource roads), an abandoned railway line, and several ATV trails. The topographic relief is highly variable (up to 274 m), having a wide range of forested, barren and boggy cover, becoming most rugged on the western and eastern edges of the map area. Pleistocene-age glacial cover is widely distributed suggesting a general east-southeast glacial-flow direction (Batterson and Taylor, 2001).

PREVIOUS STUDIES

The Random Island map area has a long and protracted history of geological investigations. Early work concentrated on detailed stratigraphic interpretations of post-Cambrian rocks (Matthew, 1899; Walcott, 1900; van Ingen, 1914; Howell, 1926). The first comprehensive geological mapping project to incorporate the Random Island map area was initiated by the Newfoundland Geological Survey (Hayes, 1948), and resulted in a summary account by the Geological Survey of Canada (Christie, 1950). Jenness (1963) consolidated Christie's early work and published the most recent geological map of the Bonavista map area (NTS 2/C). This work has also been included in a map of the Avalon Peninsula at a scale of 1:250 000 by King (1988). Additional geological studies near Random Island include an account of the Cambrian stratigraphy and trilobite faunas (Hutchinson, 1962); correlations with Scandinavia and the English Midlands based on acritarchs (Poulsen and Anderson, 1975), and subdivision and mapping of the Harcourt Group on Random Island based on six acritarch micro-floras (Martin and Dean, 1981).

Systematic geological mapping, detailed sedimentological and provenance studies have been completed on comparable stratigraphic rock units farther north in the Eastport area (O'Brien, 1987; O'Brien and Knight, 1988; Knight and O`Brien, 1988), Sweet Bay (O'Brien, 1993), Ocean Pond and Long Islands (O'Brien, 1994), and in the Bonavista and Trinity areas (O'Brien and King, 2002, 2004a, b, 2005; O'Brien *et al.*, 2006; Normore, 2010, 2011).

The Random Island map area has a rich history of mineral exploration. Early work focused on the manufacturing of bricks and the exploration and production of slate. Slate was used primarily as roofing tiles and has been reviewed in detail by Tuach (1993). More recently, exploration for sediment-hosted copper resulted in extensive geological studies along western Trinity Bay, including Random Island (*see* Froude, 2001; Dessureault, 2002; Graves, 2003; Seymour *et al.*, 2005).

REGIONAL SETTING

The Island of Newfoundland forms the northeast extension of the Appalachian orogenic system in eastern North America. The volcanic, plutonic and sedimentary rocks of the Avalon Zone in southeast Newfoundland are a part of an exotic terrane that records the accretion and break up of a proto-Gondwana supercontinent (Williams, 1979; Nance *et al*., 1991). Prior to the docking of the Avalon Zone with inboard terranes of the Appalachians in mid-Paleozoic times, multiple volcanic island-arcs were active, and their associated deep marine basins form several thick volcano-sedimentary successions (O'Brien *et al.*, 1983). The study area provides a unique cross-section of the variability in rock types observed in the Avalon Zone (Figure 2).

NEOPROTEROZOIC SEDIMENTARY AND VOLCANIC ROCKS

LOVE COVE GROUP

The Love Cove Group was first defined in the Glovertown–Clode Sound area as the Love Cove Schists Formation (Widmer, 1949), and subsequently revised (Jenness, 1957, 1958). The Group was also subdivided on the relative proportion of meta-volcanic rocks and meta-sedimentary rocks to the west in the Tug Pond map area (Forgeron and Goodman, 1971).

Jenness (1963) mapped a 3-km-thick belt of volcanic rocks, the Bull Arm Formation, near the western boundary of the Random Island map area, and next to a fault- and granite-bounded area of Love Cove Group meta-volcanic rocks to the west. This study places all volcanic rocks west of a line from Dark Hole in the south to Shoal Harbour in the north into the Love Cove Group (Figure 2), with additional subdivision into three lithologically distinct units.

The fine-grained characteristics of these volcanic rocks and its stratigraphic position below the Connecting Point Group prevent designation as Bull Arm Formation; the latter a diverse sequence of subaerially deposited bimodal volcanic rocks having a much higher percentage of interbedded sedimentary rocks.

Love Cove Group Lithofacies 1 (LC 1)

Volumetrically, the largest unit of the Love Cove Group consists primarily of green-black to dark purple, aphanitic andesitic lavas, abundant hematite stain and rare epidote

micro-veining (LC 1). This lithofacies marks the eastern boundary of the Love Cove Group in the Random Island map area separating Love Cove Group 2 (LC 2; *see* below) and the granitic bodies to the west from the sedimentary rocks to the east (Figure 2). Additional rock types, which have been observed locally within LC 1, include dark reddish-purple, aphanitic, brecciated basalt, dark purple amygdaloidal basalt, and also rare occurrences of medium green-grey, flow-laminated basalt.

Love Cove Group Lithofacies 2 (LC 2)

The Love Cove Group lithofacies 2 (LC 2) includes buff to dark-green, white-weathering, friable, lustrous, low-grade sericite and chlorite schist having epidote alteration (Plate 1). The Love Cove Group meta-volcanic rocks (LC 2) outcrop as a subtle antiform, forming a northeast-thinning wedge along the western edge of the map area in the vicinity of Deep Bight Pond. Here it is bounded by an intrusive contact with the Swift Current Granite to the southeast and a fault-bounded contact with meta-sedimentary rocks of LC 3 (*see* below) to the north (Figure 2). Metamorphism appears to be related to granitic intrusions.

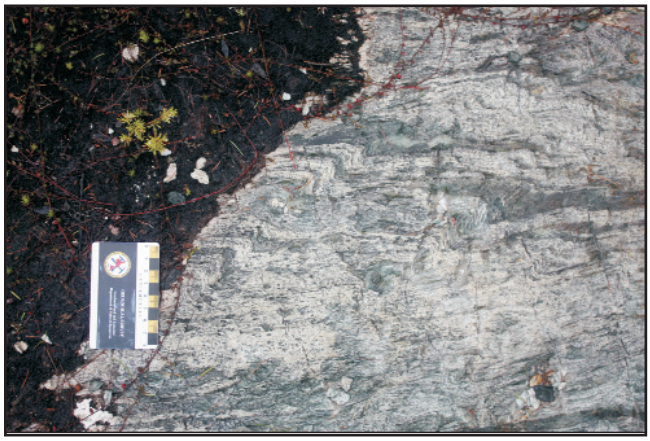

Plate 1. *Love Cove Group lithofacies 2. White-weathering chlorite and sericite schist outcropping northeast of Deep Bight Pond, near the western boundary of the map area, scalebar in cm.*

Love Cove Group Lithofacies 3 (LC 3)

The Love Cove Group lithofacies 3 (LC 3) include meta-sedimentary rocks that are spatially associated with LC 2 and the Swift Current Granite on the western boundary of the map area. Primarily dark grey-green, medium parallel-bedded siliceous siltstone interbedded with variegated (green, red, orange and white) fine-grained meta-sandstone. Rare, dark-purple metasomatized shale and a rare, light pinkish-brown felsic sill, micro-fractured and containing quartz and actinolite veining, occur in active gravel pits west of Clarenville.

The Love Cove Group is the presumed basement for this part of the Avalon Zone and as such, no known lower contact has been established. The upper contact is intercalated with the Connecting Point Group near Queens Cove, Southwest Arm; it was previously mapped as conformable with the overlying Connecting Point Group to the north of the map area, based on the trend of increasing volcanic rocks toward the base of the Connecting Point Group (O'Brien, 1987).

CONNECTING POINT GROUP

The Connecting Point Group is a deep-marine sedimentary and volcaniclastic sequence intruded by numerous mafic and felsic dykes, and rare porphyritic dykes. The group was first defined by Hayes (1948) with the type section occurring on a point of land separating Clode Sound and Goose Bay, north of the map area.

The Connecting Point Group crops out throughout the central part of the map area as an 8- to 15-km-wide north–south-trending, moderately east-dipping belt of rocks; it represents an uplifted horst, flanked to the east and northwest by younger sedimentary basins (Figure 2). It is intruded by the Clarenville Granite south of Clarenville and is intercalated with Love Cove Group volcanic rocks in the southwest corner near Queens Cove. Upper contact relationships appear to be faulted within the map area, but vary outside the map area as an angular unconformity with the Cannings Cove Formation to the north (Younce, 1970; Hussey, 1979; O'Brien, 1987) and conformably with the Bull Arm Formation to the south (McCartney, 1967; Younce, 1970).

The Connecting Point Group is subdivided into four general lithofacies, which are locally obscure due to recrystallization and silicification of the fine-grained sediment, and metasomatization adjacent to dykes. The whole group has been regionally metamorphosed to greenschist facies (Dec *et al*., 1989), probably before the deposition of the overlying Musgravetown Group (as the younger rocks do not show the same extent of metamorphism).

Connecting Point Group Lithofacies 1 (CP 1)

The Connecting Point Group lithofacies 1 (CP 1) is volumetrically dominant in the Connecting Point Group. CP 1 consists of a monotonous succession of thin- to medium-bedded dark grey-green, well-indurated siltstones that may be massive, planar parallel or wavy laminated (Plate 2A). Silty laminations cap each bed occurring as either a single black silty lamina, couplets, or many closely spaced lamina-

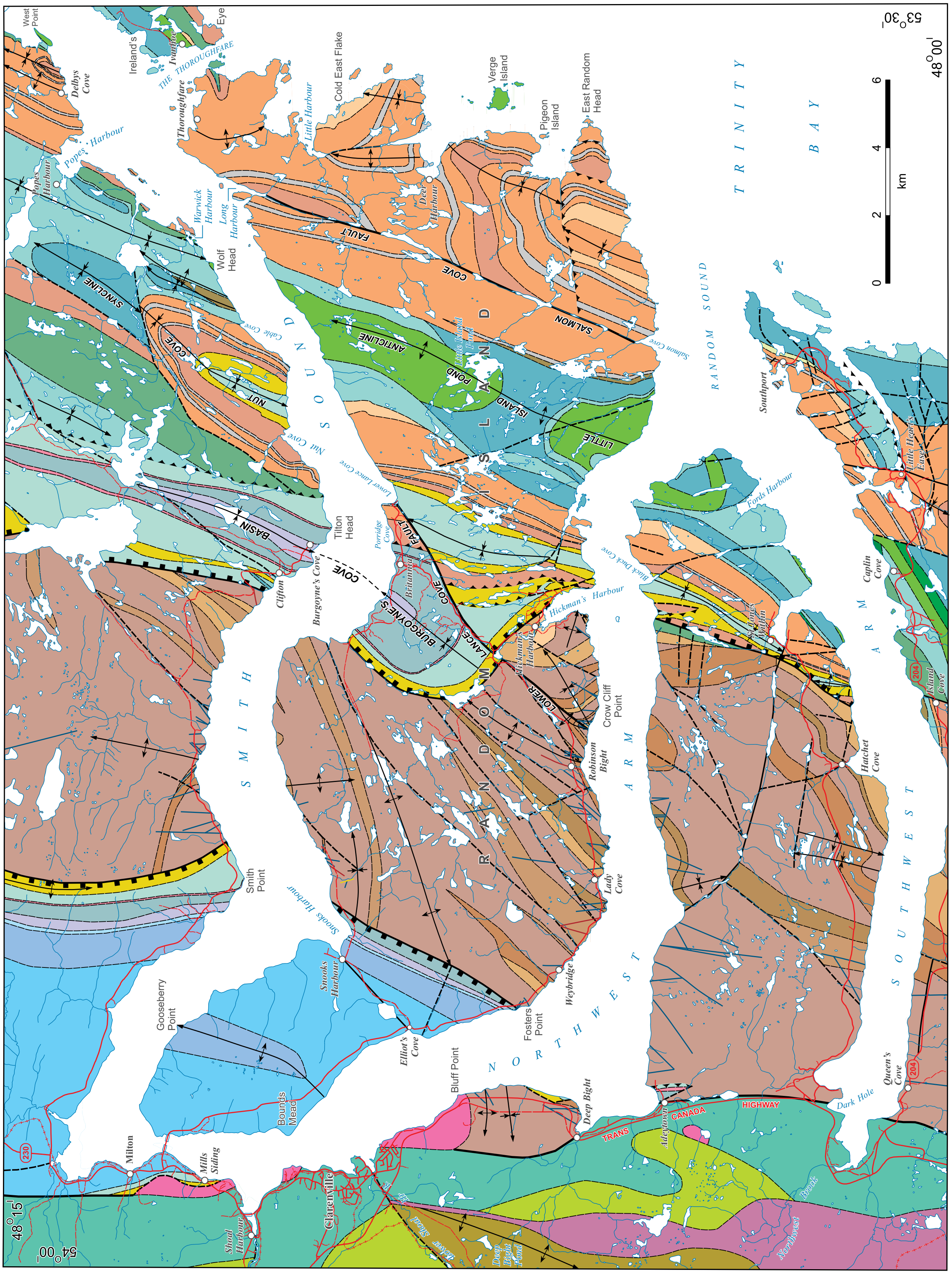

Figure 2. *Geology of the Random Island map sheet (NTS 2C/04).*

LEGEND

ORDOVICIAN

HARCOURT GROUP

Clarenville Formation: Dark-grey to black, rusty on bedding planes, thin parallel-laminated mudstones having saucer-shaped cone in cone concretions

CAMBRIAN

Elliotts's Cove Formation: Silver-grey, graphitic, micaceous mudstones interbedded with dark-grey, light brown-weathering, thin medium-bedded, well indurated fine-grained sandstone and siltstone

Manuels River Formation: Black to dark-brown weathers dark-grey, thin parallel-laminated to thick bedded, fissile and friable siltstone interbedded with rare thin light yellow-brown, silty limestone beds

ADEYTON GROUP

Chamberlains Brook Formation: Dark-red manganiferous mudstone, calcareous at the base

Brigus Formation: Red, grey and green shale with occasional pink to red nodular limestone beds

Smith Point Formation: Fossiliferous pink to brick-red indurated limestone with dark-red shale interbeds

Bonavista Formation: Red and grey intensely cleaved shales with light-pink limestone nodules

EARLY CAMBRIAN

Random Formation
White, pink near the base, medium- to thick-bedded quartzarenite interbedded with green-grey, fine- to medium-grained sandstone and grey siltstone

NEOPROTEROZOIC

MUSGRAVETOWN GROUP

Crown Hill Formation

Broad Head facies: Dark-red to pink, pebble conglomerate interbedded with purple-pink sandstone

Red Cliff facies: Dark purple-red, thin- to medium-bedded, fine- to medium-grained sandstone containing bright-red, thin laminated to disrupted siltstone beds and sand dykes

Blue Point Horizon: Grey to green (locally brown where copper and pyrite mineralization occur) laminated siltstone, mudstone and fine- to locally coarse-grained, sandstone

Duntara Harbour facies: Dark-purple to red, thin-bedded siltstone interbedded with light-grey wavy bedded to discontinuous fine-grained sandstone with polygonal desiccation cracks

Brook Point facies: Tan to yellow siliceous flow-banded rhyolite flow with rare pink thin wavy laminations and gypsum pseudomorphs distributed near the top of the bed

Rocky Harbour Formation

Herring Cove facies: Pink, elongate to ropey shaped cobble to boulder-size felsic peperites intruded into unconsolidated siltstones and fine-grained sandstones

Kings Cove Lighthouse facies: Dark grey-purple to light grey-pink, medium- to coarse-grained sandstones, interbedded with dark-purple wavy laminated siltstones and dark-purple mud drapes

Kings Cove North facies: Green-grey, occasionally dark-grey or tan to light-yellow, thin parallel to wavy laminated siltstone, coarsening up section to sandstone

Monk Bay facies: Dark-grey, thick-bedded, fine- to very coarse-grained, poorly sorted, low-angle crossbedded sandstone and pebble conglomerate with large-scale ripples

Cape Bonavista facies: Dark-grey to light pink-grey, trough crossbedded, medium- to coarse-grained arkosic sandstones

Jones Pond subfacies: Dark-grey to black, polymictic, well-rounded, clast-supported, poorly sorted pebble to cobble conglomerate

Bull Arm Formation
Lithologically diverse group of volcanic and sedimentary rocks including vesicular basalts, ignimbrites, peperites, tuffs, agglomerates, sandstones and siltstones

Felsic Dykes: Orange-pink coarse-grained biotite granite dykes ranging from 5 to 40 m wide, occur only within the Connecting Point Group

Mafic Dykes: Dark grey-green or blue-grey aphanatic, basalt dykes. Mafic dykes range from 1 to 15 m thick, occurring as swarms within the Connecting Point Group

Porphyritic Dykes: Dark-grey porphyritic dykes are rare on the margins of the Connecting Point Group. White feldspar plagioclase phenocrysts are 2 to 20 mm long, tabular to blocky in shape

Clarenville Granite
Orange-pink, equigranular, medium-grained, biotite granite and sericite, chlorite and epidote alteration.

Swift Current Granite
Orange-pink medium-grained biotite, hornblende granite and granodiorite and rare fluorite veins

CONNECTING POINT GROUP

Connecting Point 1: Dark-green thin- to medium-bedded, siliceous siltstones separated by single black laminations, rare couplets, with a rusty hematite coating

Connecting Point 2A: Interbedded dark-green thin- or medium-bedded siliceous siltstone and grey to tan, thin- or medium-bedded very fine- or fine-grained, massive quartz arenite

Connecting Point 2B: Rhythmic beds of grey-green thin-bedded, very fine- to fine-grained massive quartz arenite normally grading into siltstone. Light-grey normally graded coarse- to fine-grained tuffs

Connecting Point 3: Blue, grey and green thick-bedded, massive, very fine- to medium-grained quartzarenite, occasionally sublitharenite with rare large-scale slump features

Connecting Point 4: Chaotic beds of boulder-size siltstone and sandstone intraclasts are preserved floating within a dark-brown andesitic, porphyritic matrix

LOVE COVE GROUP

Love Cove 1: Dark green-black to dark-purple, aphanitic andesitic lavas with abundant hematite stain and rare epidote micro-veining

Love Cove 2: Buff, greenish, friable, flaky in parts, low-grade sericite and chlorite schist

Love Cove 3: Dark grey-green, medium parallel-bedded siliceous siltstone interbedded with variegated (green, red, orange and white) fine-grained metasomatized sandstone

SYMBOLS

Geological contact .....

Normal fault .....

Major fault .....

Minor fault .....

Assumed fault .....

Thrust fault .....

Anticline with plunge .....

Syncline with plunge .....

Road (paved, gravel, forestry, cart track) .....

Abandoned railway .....

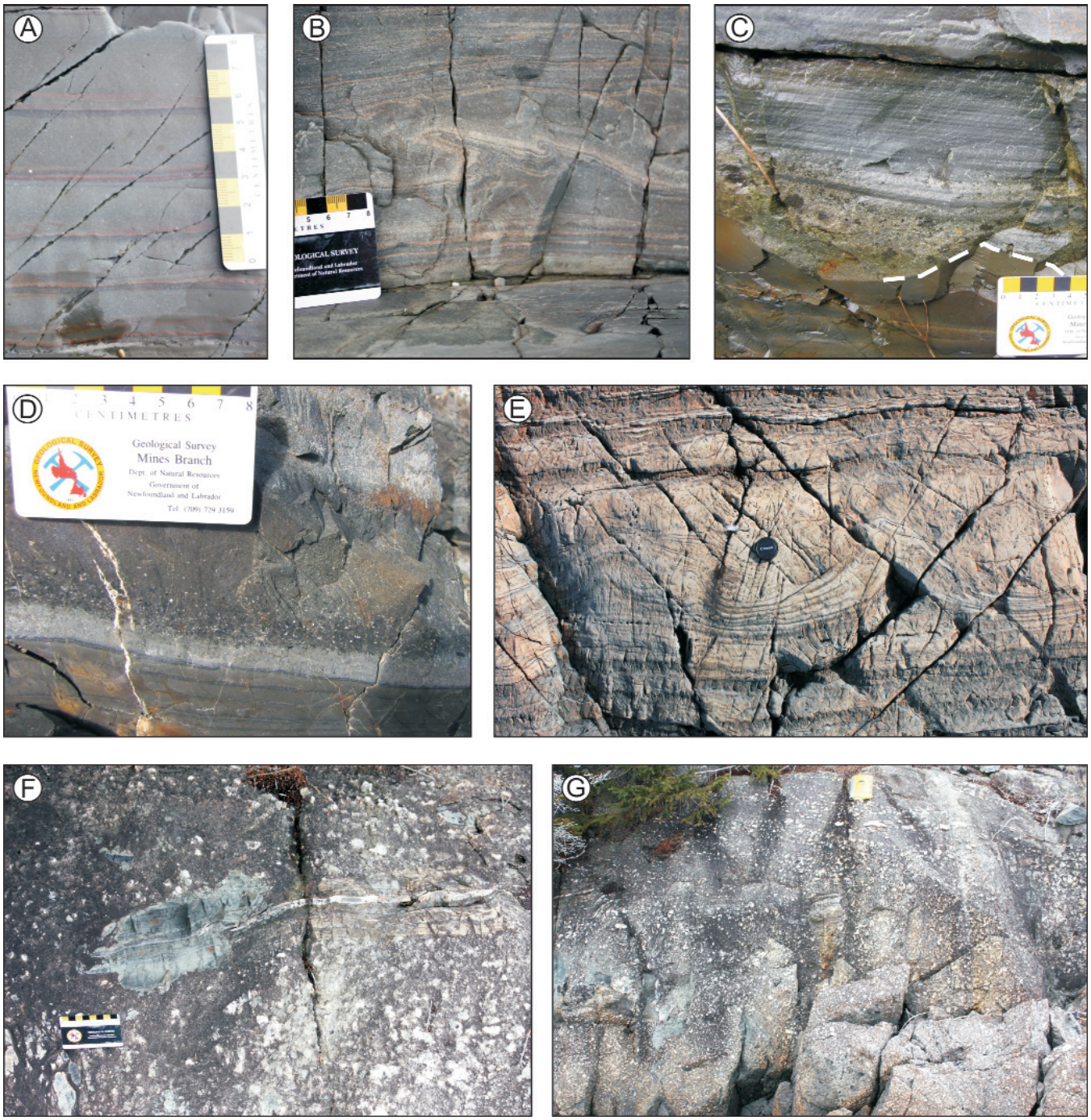

Plate 2. *Connecting Point Group in the Random Island map area. A) Connecting Point Group lithofacies 1, dark grey-green, siliceous thinly bedded siltstones separated by individual black laminations with hematite haloes, outcropping west of Black Duck Cove, Northwest Arm, scalebar in cm, B) flame structures within lithofacies 1 of the Connecting Point Group near Upper Harbour Point, west side of Hickman's Harbour, scalebar in cm, C) CP2B, normally graded bouma sequence with erosional base, Hatchet Cove, Southwest Arm, erosional base highlighted by white dashed line, scalebar in cm, D) light-grey thinly bedded tuff horizon with the CP 2B lithofacies, outcropping on Route 205 between Hatchet Cove and St. Jone's Within, scalebar in cm, E) CP3, soft-sediment deformation within the thin- to medium-bedded, very fine-grained sandstones near Crow Cliff Point, north side of Northwest Arm, lens cap 5.8 cm diameter, F) CP4, large, grey-green, tabular siltstone intraclasts floating in a volcaniclastic matrix, west of Hickman's Harbour, scalebar in cm, G) CP4, reverse graded bedding of a very thick volcaniclastic, poorly sorted conglomerate west of Hickman's Harbour, fieldbook 19 cm long.*

tions (probably representing hemipelagic deposition). Soft-sediment deformation such as flame structures (Plate 2B) have been observed in some beds. The siltstones have been recrystallized and, in places, are highly siliceous, almost cherty. In proximity to dykes, the siltstones have been metasomatized and heavily silicified. Contact metamorphism has been observed up to a 4 m locus of dykes.

Connecting Point Group Lithofacies 2A (CP 2A)

Connecting Point Group lithofacies 2A (CP 2A) occurs intermittently throughout the middle and upper stratigraphic levels of the Connecting Point Group on the Random Island map area. This lithofacies is a heterolithic succession of interbedded thin- or medium-bedded siliceous siltstone (commonly massive) and thin- or medium-bedded very fine- or fine-grained, massive quartz arenite. The sandstones, like the siltstones, have been recrystallized, are highly quartzose and have a 'sugary' texture.

Connecting Point Group Lithofacies (CP 2B)

Connecting Point Group lithofacies 2B (CP 2B) has a close lithofacies association with CP 2A, generally stratigraphically above. It consists of rhythmic beds of grey-green, thin-bedded, fine-grained massive quartz arenite normally grading into siltstone that may be massive or wavy laminated (Plate 2C). Scoured surfaces at the base of these beds indicate the erosive nature of a turbidite bed. Another noteworthy feature of this lithofacies is the occurrence of possible tuffs within the siltstone. Thin beds of white, fine-grained, angular, well-sorted tuffs are found at the base and top of some of the normally graded packages (Plate 2D). Rare calcareous oval-shaped concretions and soft-sediment deformation also occur in the siltstones.

Connecting Point Group Lithofacies 3 (CP 3)

Connecting Point Group lithofacies 3 (CP 3) occurs irregularly throughout the Random Island map area and is more common in the upper half of the unit. It consists of thin to thick beds of blue-grey-green, light brown-weathering, very fine- to medium-grained quartz arenite with rare sublitharenite. The sandstones have been recrystallized and have a 'sugary' texture and occasionally exhibit large-scale slump features (Plate 2E). A blue-grey, clast-supported, polymictic, massive, granule conglomerate with subangular to rounded clasts was noted at one isolated outcrop west of Hatchet Cove on the north side of Southwest Arm within CP 3.

Connecting Point Group Lithofacies 4 (CP 4)

A thick volcaniclastic lithofacies (CP 4) has been mapped in the uppermost strata of the Connecting Point Group in the Random Island map area (Figure 2). Dark-brown, poorly sorted, volcanic matrix-supported conglomerate having large irregular-shaped siltstone intraclasts (Plate 2F) are interbedded with dark-grey, white-weathering, thick beds of very coarse-grained poorly sorted volcaniclastic sandstone. Conglomerate and sandstone units pinch out laterally into siltstones and reverse grading has been noted in some conglomerate beds (Plate 2G).

Mafic Dykes

The Connecting Point Group is intruded by mafic dykes throughout the map area ranging from 3 to 15 m thick (Plate 3A). The dykes are fine, rarely coarse-grained, dark grey-green or blue-grey, equigranular diabase to diorite. Minor disseminated pyrite is ubiquitous throughout the dykes. Whereas generally restricted to the Connecting Point Group, a series of three small mafic dykes were found crosscutting sedimentary rocks of the Crown Hill Formation on the north coast of Southwest Arm, west of Bailey's Cove (Plate 3F).

Felsic Dykes

Felsic dykes occur less often but follow the same structural weakness as their mafic counterpart. They occur primarily within the Connecting Point Group and are generally associated with mafic dykes and large northeast-trending fault systems. At one particular area, both felsic and mafic dykes can be traced from the coastline of Northwest Arm to Route 231 near Robinson Bight on Random Island. At this location, the contact relationship is not clear with a possible chilled or metasomatized margin for the mafic dyke (Plate 3B). A second felsic–mafic dyke combination on the north side of Northwest Arm, between the communities of Weybridge and Lady Cove, exhibits clear timing of dyke formation with the mafic precluding and possibly creating pathways for subsequent felsic volcanism. At the second location, an orange-pink, coarse-grained, biotite granite dyke approximately 5 m thick, is found with a 1-m-thick mafic dyke on each side. There are also cobble-sized clasts of the adjacent mafic dykes contained within the granitic dyke (Plate 3C). A large 30-m-thick felsic sill occurs on the north side of Smith Sound, west of the community of Clifton (Plate 3D).

Porphyritic Dykes

Only two porphyritic mafic dykes were mapped in the Random Island map area. One occurs near the western edge of the Connecting Point Group sedimentary rocks at Snooks Harbour and has a shallow westerly dip, while the second outcrops in Hickman's Harbour and dips steeply to the east. White tabular feldspar phenocrysts range from 2 to 20 mm in length and are generally found aligned parallel to each other (possible flow indicator) or less commonly two phenocrysts are seen overlapping in a cross shape (Plate 3E).

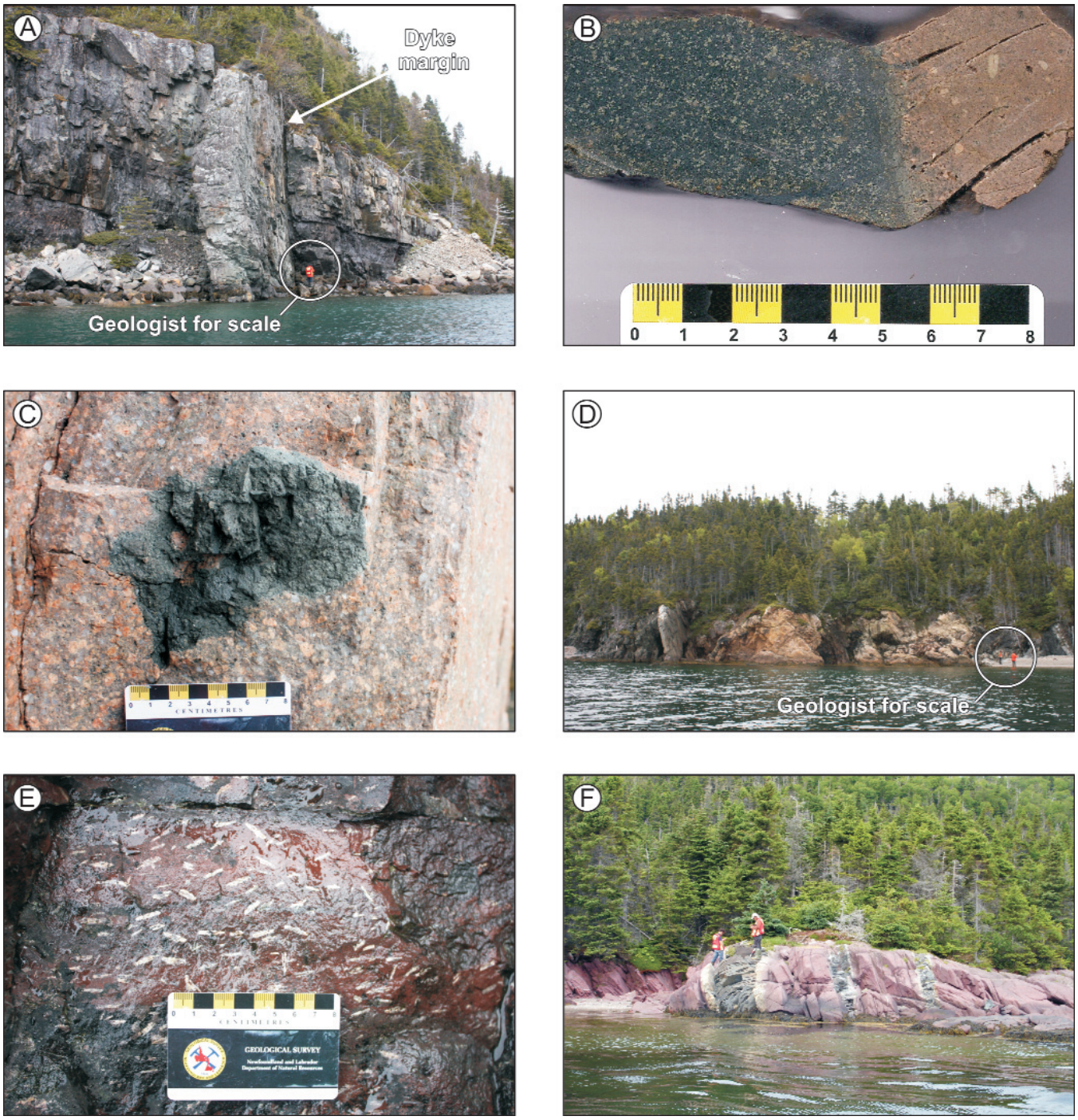

Plate 3. *Various dykes found in the Random Island map area. A) 4-m-thick mafic dyke crosscutting Connecting Point Group sedimentary rocks, west of Hickman's Harbour, B) hand sample of contact between mafic and felsic dyke at Robinson Bight, Northwest Arm, scalebar in cm, C) felsic dyke with entrained mafic clast, outcropping along the coastline between Weybridge and Lady Cove, scalebar in cm, D) 30-m-thick felsic sill in the Connecting Point Group, west of Clifton, north side of Smith Sound, E) porphyritic dyke outcropping in Hickman's Harbour (scalebar in cm), F) rare mafic dykes crosscutting sedimentary rocks of the Crown Hill Group west of Bailey's Cove, Southwest Arm, geologists for scale.*

MUSGRAVETOWN GROUP

The Musgravetown Group of Hayes (1948) was divided into five formations in the Bonavista Bay area (Jenness, 1963). The five formations of Jenness (1963), in ascending order, are the Cannings Cove, Bull Arm, middle undifferentiated, Rocky Harbour and Crown Hill. These divisions extend to the south into the Isthmus of Avalon. McCartney (1967) replaced Jenness' middle undifferentiated and Rocky Harbour formations with the Big Head, Maturins Pond and Trinny Cove formations. Only the Bull Arm, Rocky Harbour and Crown Hill formations have been recognized on the Random Island map area.

Bull Arm Formation

First described by Jukes (1843), the Bull Arm Felsite was mapped as a volcanic unit interbedded with shale and sandstone near the base of the Musgravetown Group (Hayes, 1948). It was renamed the Bull Arm Formation by Jenness (1963), who placed it stratigraphically above the Cannings Cove Formation and intercalated with the overlying Big Head Formation.

Volcanic rocks of the Bull Arm Formation crop out in six main locations throughout the eastern half of the map area (Figure 2), with the largest extent occurring as a fault-bounded block separating the Cambrian Bonavista Formation from the Crown Hill Formation on the north side of Smith Sound, west of Nut Cove. Volcanic rocks also occur in Smith Sound from Warrick's Harbour to Pope's Harbour, east of Delby's Cove, and near the Thoroughfare, as well as west of Black Duck Cove in Northwest Arm and from Island Cove to Caplin Cove on the south side of Southwest Arm.

Volcanic rocks also occur stratigraphically between the Rocky Harbour and Crown Hill formations on the Random Island map area. This is higher in stratigraphy than generally accepted for the Bull Arm Formation, a tentative placement has been assigned here, but it is also noted that this may be a more robust and extensive development of the volcanism associated with both the Herring Cove and Brook Point facies, discussed in more detail below.

Typical rocks of the Bull Arm Formation in the Random Island map area are lithologically diverse, including vesicular basalts, volcanic breccias (Plate 4A), ignimbrites (Plate 4B), peperites (Plate 4C), tuffs (Plate 4D), pillow lavas (Plate 4E), and agglomerates (Plate 4F). Interbedded with the volcanic rocks are sedimentary and volcaniclastic rocks. An 8-m-thick succession of volcanic and volcaniclastic rocks east of Burgoyne's Cove provides a great example of the variability found in this facies. Thick-bedded, dark-purple vesicular basalt is overlain by a cobble to boulder volcanic breccia having a pink felsic matrix, followed by a purple basaltic ignimbrite unit containing partially melted internal clasts. The ignimbrite is, in turn, overlain by a volcaniclastic unit of interbedded fine-grained sandstone and granule to pebble conglomerates. The top of the volcaniclastic rocks are intruded by a 50-cm-thick peperitic horizon containing boulder-sized, irregular-shaped clasts, having a dark-grey, thin outer margin. This peperite unit is reminiscent of similar horizons in the Herring Cove facies providing a possible link to this volcanic unit. The entire sequence is capped by a 30-cm-thick coarse-grained tuff.

Rocky Harbour Formation

The type section for the Rocky Harbour Formation is found in the Random Island map area at a well-defined harbour on the north side of the entrance to Southwest Arm. It was originally labelled as Rocky Harbour on the map of Jenness (1963), but current topographic maps have it as Ford's Harbour. The Rocky Harbour Formation comprises a succession of tidal-influenced deltaic and wave-dominated lower shoreface sedimentary rocks exposed in a 2 to 3.5 km belt, striking north-northeast, across the eastern side of the map area, as the core of the Little Island Pond anticline (Figure 2). Following Normore's (2011) lithostratigraphic subdivision of the Rocky Harbour Formation on the Bonavista Peninsula, this report identifies only the uppermost facies, including Cape Bonavista, Monk Bay, Kings Cove North, Kings Cove Lighthouse, and Herring Cove facies.

The upper contact of the Rocky Harbour Formation is transitional with the Crown Hill Formation. The base, generally not exposed throughout the map area, is structurally complex, truncated by Bull Arm Formation volcanic rocks north of Smith Sound. The Rocky Harbour Formation can be correlated with the Hearts Content Formation in Trinity, Placentia and St. Mary's bays (Fletcher, 2006) and the Trinny Cove Formation in western Trinity Bay and eastern Placentia Bay (McCartney, 1967).

Cape Bonavista Facies

The Cape Bonavista facies is the lowermost subdivision of the Rocky Harbour Formation in the Random Island map area; it is exposed over the eastern part of the map area, centred on the Little Island Pond anticline (Figure 2). Sedimentary rocks assigned to this facies also outcrop at the entrance to St. Jone's Within, the south side of Random Sound, Verge Island, West Point, Ivanhoe, Wolf Head and Warrick Harbour. Dark-grey to light pink-grey, trough crossbedded, medium- to coarse-grained arkosic sandstones (Plate 5A) of the Cape Bonavista facies have a slightly mottled appearance caused by a reduced dark-grey halo surrounding dark-grey, wispy, thin siltstone interbeds. A subunit of this facies,

Plate 4. *Bull Arm Formation, Musgravetown Group. A) Volcanic breccia with felsic matrix located on the west limb of the Nut Cove syncline, scalebar in cm, B) purple, poorly sorted agglomerate with red aphanatic matrix overlying A, fieldbook 19 cm long, C) peperite horizon interbedded with volcaniclastics overlying B on the west limb of the Nut Cove syncline, scalebar in cm, D) grey, coarse-grained tuff capping the volcanic sequence on the west limb of the Nut Cove syncline, hammer handle in 10 cm increments, E) pillow basalts located near southwest side of British Harbour, scalebar in cm, F) porphyritic boulder agglomerate with dark-purple vesicular andesite matrix located near Warrick Harbour, Smith Sound, hammer handle in 10 cm increments.*

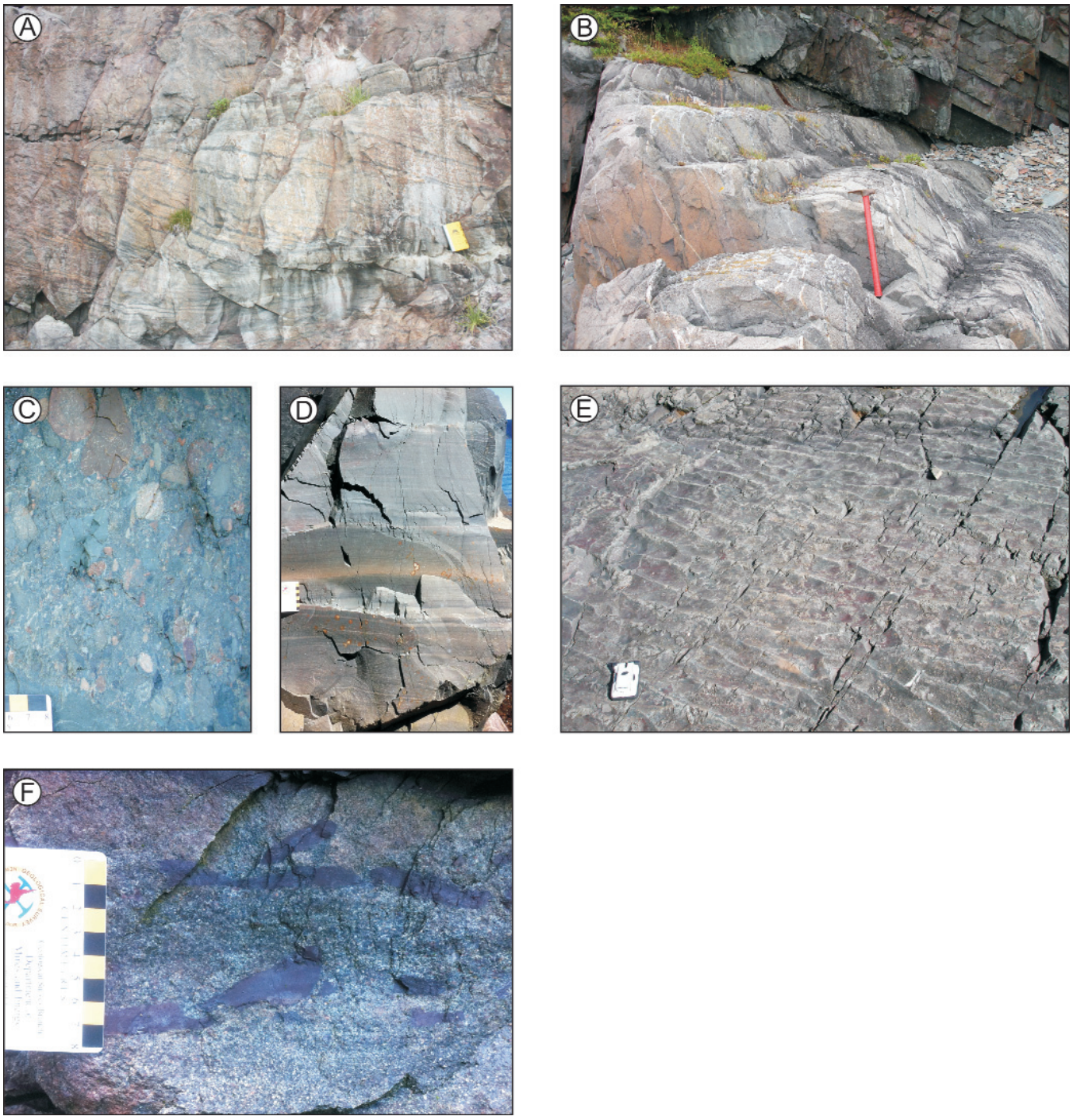

Plate 5. *Rocks typical of the Rocky Harbour Formation in the Random Island map area. A) Trough crossbedded, fine- to coarse-grained sandstones of the Cape Bonavista facies, near Wolf Head, north shore of Smith Sound, fieldbook is 19 cm long, B) large-scale coarse-grained ripples of the Monk Bay facies, east of Salmon Cove on the north shore of Random Sound, hammer is 73.5 cm long, C) polymictic well-rounded, clast-supported pebble to cobble conglomerate of the Cape Bonavista facies west of Island Cove on the south short of Southwest Arm, scalebar in cm, D) green-grey, light-grey and tan wavy laminated siltstone of the Kings Cove North facies, southeast of Passenger Point, Random Sound, scalebar in cm, E) symmetrical sharp-crested wave ripples of the Kings Cove North facies, west of Ford's Harbour, compass 10.5 cm long, F) grey coarse-grained, thin- to medium-bedded sandstone interbedded with disrupted dark-purple siltstones and imbricated siltstone rip-up clasts, scalebar in cm.*

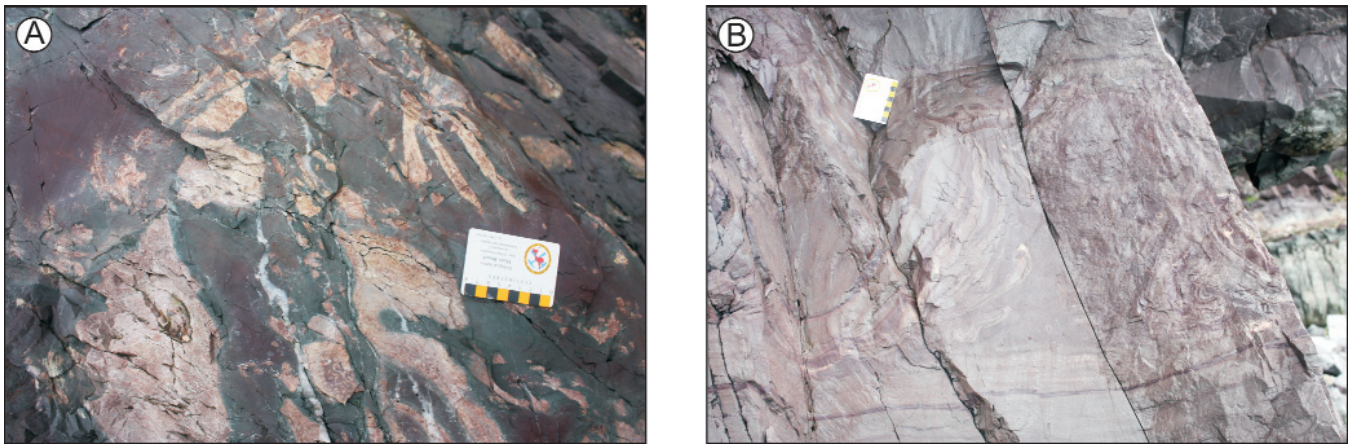

Plate 6. *Herring Cove facies, Rocky Harbour Formation, Musgravetown Group. A) Peperite horizon with globular to elongate felsic body intruded into hornsfelsed dark-purple mudstone, northeast of Caplin Cove, southern shore of Southwest Arm, B) fluid or gas escape structures occurring immediately above the peperite horizon in A.*

a polymictic, clast-supported pebble to cobble conglomerate (Plate 5C) was located in fault-bounded blocks on the southern boundary of the map area, near Caplin Cove and Island Cove, and is correlated with the Jones Pond facies of O'Brien and King (2002).

Monk Bay Facies

Rocks of the Monk Bay facies only outcrop in two areas; west of Salmon Cove in Random Sound, and east of Cable Cove on the north shore of Smith Sound. The main rock type is dark-grey, thick-bedded, fine- to coarse-grained, poorly sorted, low-angle, trough crossbedded sandstone. The diagnostic feature is the large-scale ripples (Plate 5B). The small areal extent of this facies and the interfingering nature with Kings Cove North facies on the Random Island map area, places it higher in the stratigraphy than that farther to the north, and may represent an isolated storm event or a paleo-embayment that extended the lower shoreface farther into the tidal flats of the Kings Cove North facies.

Kings Cove North Facies

The Kings Cove North facies was first described by O'Brien and King (2002) as white-weathering, finely laminated, light-grey, fissile siltstone occurring at the top of the Rocky Harbour Formation. The Kings Cove North facies is intercalated and grades laterally with the Kings Cove Lighthouse facies, and outcrops over large areas in the eastern half of the map area (Figure 2). It is green-grey, occasionally dark-grey or tan to light-yellow, thin, parallel to wavy laminated siltstone (Plate 5D), becoming interbedded with fine-grained sandstone lens, up section. Symmetrical sharp crested wave ripples (Plate 5E) were observed in this facies west of Ford's Harbour and are diagnostic of wave-influenced shallow-marine depositional settings.

Kings Cove Lighthouse Facies

The type section for this facies is the coastal section below the lighthouse at Kings Cove in the Bonavista map area NTS 2C/06 (Normore, 2010). Placement of the Kings Cove Lighthouse facies at the top of the Rocky Harbour Formation is only arbitrary as lateral facies transition and interfingering with the Kings Cove North facies has been observed throughout the Random Island, Trinity and Bonavista map areas. It crops out in several areas on the eastern part of the map area, particularly north of Cable Cove, in the core of the Little Island Pond anticline, east of St. Jone's Within and east of Little Heart's Ease. This facies consists of dark grey-purple to light grey-pink, thin- to medium-bedded, medium- to coarse-grained sandstones, interbedded with dark-purple to grey wavy laminated and tabular siltstone rip-up clasts (Plate 5F).

Herring Cove Facies

The distinctive peperitic horizons of the Herring Cove facies were only observed at one location east of Caplin Cove on the north side of Southwest Arm. At this location, a 1.5-m-thick peperite horizon contains globular and elongate felsic mass intruded into dark-purple hornfelsed mudstone (Plate 6A) overlain by large fluid or gas escape structures (Plate 6B). This facies is more extensively developed in the Trinity map area (Normore, 2011). The Herring Cove facies occurs near the top of the Rocky Harbour Formation and may represent a period of renewed volcanism during a fundamental change in depositional environments from marine to terrestrial, which may be diachronous with the Brook Point facies. It may also be related to subunit 15a of the upper Rocky Harbour Formation, where four separate buff to pale yellow-green devitrified rhyolite sills occur interbedded with the sedimentary rocks (O'Brien and Knight, 1988).

Crown Hill Formation

The Crown Hill Formation introduced by Jenness (1963) was subdivided on the Bonavista Peninsula by O'Brien and King (2005) into a series of nine facies. Subsequent mapping (Normore, 2010, 2011) has redefined the stratigraphy of the Crown Hill Formation on the Bonavista Formation. The Crown Hill Formation is exposed over a large portion of the eastern half of the Random Island map area, but its stratigraphic thickness is slightly condensed compared to equivalent strata to the north, suggesting a thinning trend to the south. It covers a large area due to a series of north-northeast-trending folds causing a repetition of strata. The main facies of the Crown Hill Formation found on the Random Island map area include, in ascending order, the Brook Point, Duntara Harbour, Red Cliff (containing the Blue Point horizon subfacies) and Broad Head facies.

Brook Point Facies

Gypsum pseudomorphs found previously at the top of a yellow 1.5 m bed in the Bonavista map area were used to indicate a sabkha-type depositional environment (Seymour *et al.*, 2005; Normore, 2010). An identical bed was mapped on the south side of Random Sound, northeast of the community of Southport (Plate 7A and B), where it separates the Crown Hill and Rocky Harbour formations. A volcanic origin is now proposed for the Brook Point facies as a distinct yellow and pink flow-banded rhyolite, and may be correlative with the Herring Cove facies as they both exist near the transition between the Rocky Harbour and Crown Hill formations.

Duntara Harbour Facies

The Duntara Harbour facies outcrops in several locations over the eastern half of the map area (Figure 2); northeasterly dipping beds outcrop between Little Heart's Ease and Southport, a syncline west of East Random Head on the north side of Random Sound, as a sliver east of Lower Lance Cove on the south side of Smith Sound, as a thin unit near Ivanhoe on Ireland's Eye, near Cold East Flake on the eastern edge of Random Island, and as a thin unit at Warrick Harbour in Smith Sound.

Dark-purple to red, thin-bedded siltstone interbedded with light-grey wavy-bedded to discontinuous fine-grained sandstone are the main rock types of the Duntara Harbour facies. The facies contains sedimentary structures including polygonal dessication cracks (Plate 7C–D), and asymmetric ripples. The Duntara Harbour facies is transitional with the overlying Red Cliff facies and may laterally change into the underlying Brook Point facies. Unidirectional sedimentary structures such as, asymmetric ripples, indicate the Duntara Harbour facies was deposited in a fluvial system that had regular extended periods of drought, demonstrated by the polygonal desiccation cracks.

Red Cliff Facies

The Red Cliff facies outcrops over two main belts across the eastern half of the Random Island map area. The largest and most easterly belt ranges from 2.5 to 7 km thick, extending from Delby's Cove in the northeast corner of the map area southwest to Little Heart's Ease. The second belt is up to 1.5 km thick, focused around the Nut Cove syncline in the north and pinching out to the south at Baileys Cove on the north shore of Southwest Arm. It consists of dark purple-red, thin- to medium-bedded, fine- to medium-grained sandstone containing bright red, thinly laminated to disrupted siltstone beds (Plate 7F) and sand dykes (Plate 7E). The Red Cliff facies has a transitional upper boundary with the overlying Broad Head facies and contains the prospective copper-mineralized Blue Point horizon. The sedimentary structures found in the Red Cliff facies indicate rapid burial creating over-pressure conditions in the subsurface with the resulting sand dykes and disrupted bedding occurring as equilibrium was achieved.

Blue Point Horizon

The Blue Point horizon is a grey, reduced siltstone and fine-grained sandstone unit completely contained within the Red Cliff facies and is the primary target for sediment-hosted copper on the Bonavista Peninsula (*e.g.,* Froude, 2001; Seymour *et al.*, 2005; Hinchey, 2010). The Blue Point horizon outcrops at multiple locations throughout the eastern portion of the map area (Plate 7G). It occurs as two discreet units, 10 to 15 m thick and consists of fine-laminated, grey to green (locally brown where copper and pyrite mineralization occur) siltstone, mudstone and fine- to locally coarse-grained sandstone. Copper mineralization is confined to the southeastern part of the map area surrounding Little Heart's Ease. One new occurrence was located in an active quarry between Caplin Cove and Little Heart's Ease (Plate 7H).

Broad Head Facies

The Broad Head facies is the stratigraphic top of the Musgravetown Group and appears to be conformably overlain by the Random Formation in the Random Island map area. It is a coarse-grained conglomeratic unit that interfingers with the underlying Red Cliff facies. It consists primarily of dark-red to pink, pebble conglomerate (Plate 7I) interbedded with purple-pink, sandstone. The thick-bedded, large-scale trough crossbedded, coarse-grained sandstone contains dark purple-red mudstone rip-up clasts, and locally displays irregular erosional boundaries with pebble lags at the basal contact. The conglomerates are thick bedded, subrounded, poorly sorted, and crudely stratified.

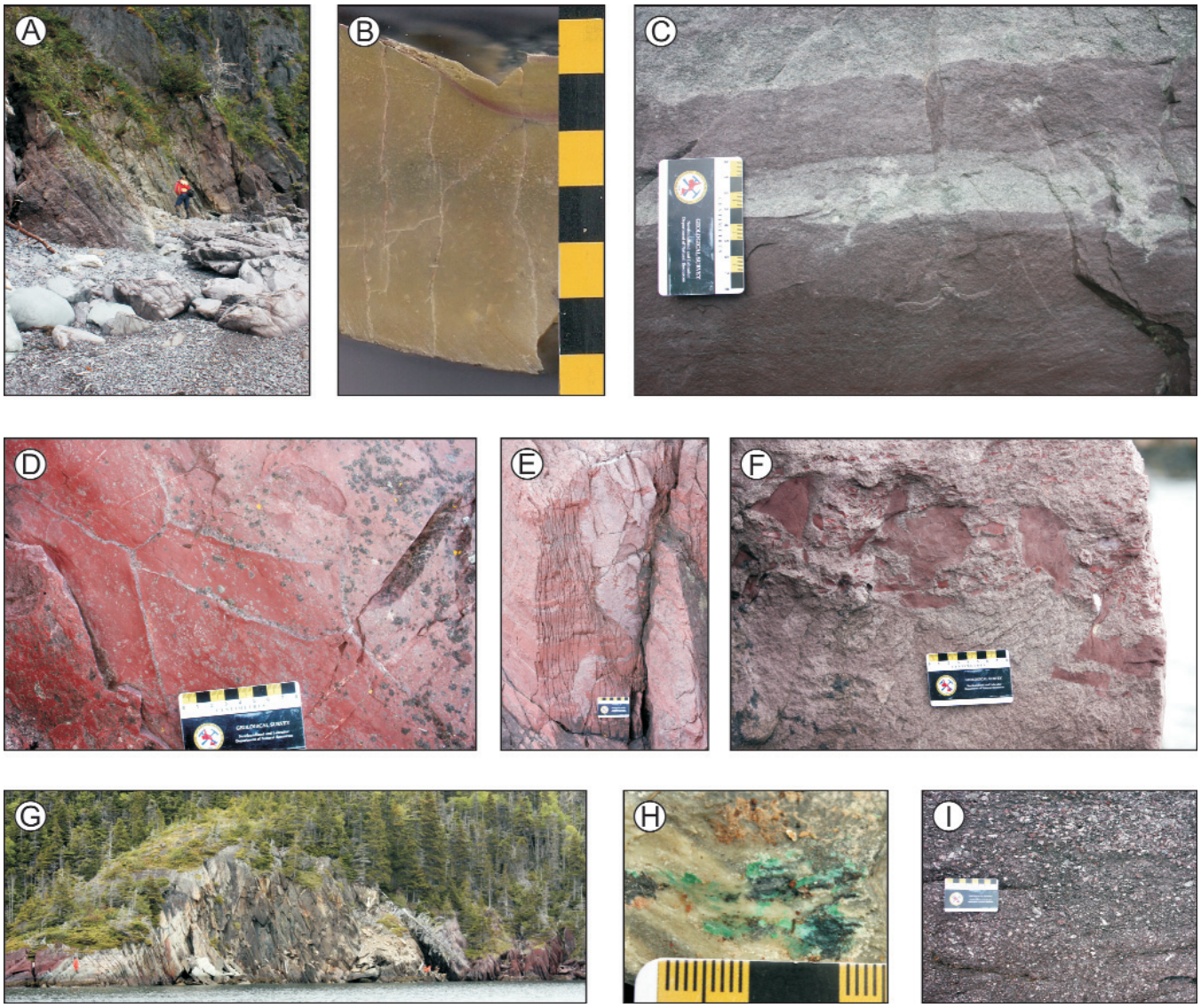

Plate 7. *Crown Hill Formation, Musgravetown Group. A) Brook Point facies near the base of the Crown Hill Formation, east of Southport on the south side of Random Sound, geologist for scale, B) close-up of rock slab from the Brook Point facies from outcrop in (A), showing the development of bladed crystals and thin pink laminations reminiscent of beds at the Brook Point facies type section north of King's Cove, Bonavista Bay, scalebar in cm, C) dessication cracks infilled with sand, diagnostic of the Duntara facies, located on Route 204 between Caplin Cove and Little Heart's Ease, scalebar in cm, D) plan view of dessication cracks in the Duntara Harbour facies to the east of the map area on Anthony Island, scalebar in cm, E) sand dyke and associated water expulsion features of the Red Cliff facies, located on Pigeon Island, Random Head Harbour, scalebar in cm, F) dark-red siltstone rip-up clasts floating in a light-pink sandstone matrix, located near Little Harbour on the eastern edge of Random Island, scalebar in cm, G) upper reduced unit of the Blue Point horizon on the eastern limb of the Nut Cove syncline, geologists for scale, H) chalcocite and malachite mineralization from a quarry between Caplin Cove and Little Heart's Ease, scalebar in cm, I) poorly sorted, thick-bedded granule to pebble conglomerate of the Broad Head facies, located at Long Harbour, near the entrance to Smith Sound, scalebar in cm.*

POST-CAMBRIAN ROCKS

Two Cambrian fault blocks are found in the Random Island map area separated by a horst of Connecting Point Group sedimentary and volcaniclastic rocks (Figure 2). The thickest fault block is located in the centre of the map area and exists as two synclines created by additional folding and faulting. The second fault block is found in the northwest and contains the youngest sedimentary rocks in the map area. The rocks range from shallow-marine quartz arenites

to deep-marine shales and include in ascending order, the Random Formation, and the Adeyton and Harcourt groups.

Random Formation

The Early Cambrian Random Formation conformably overlies the Crown Hill Formation and is disconformably overlain by the Early Cambrian Bonavista Formation. The Random Formation was originally defined by Walcott (1900) redefined by Christie (1950) and Greene and Williams (1974). The type section is east of Hickman's Harbour, north side of Northwest Arm. The formation is widely distributed throughout the map area, including near Milton, the coastline north of Deep Bight, east of Smith Point, and several localities in the Nut Cove syncline and Burgoyne's Cove Basin.

The Random Formation is a very distinct unit of white herring-bone crossbedded, quartzarenite (Plate 8F) interbedded with green-grey, coarse-grained sandstone and grey siltstone. It was deposited in a storm-influenced macro-tidal setting (Hiscott, 1982), during a globally recorded transgressive event (Vail *et al.*, 1977). The contact with the underlying Musgravetown Group appears to be conformable at the type section (Plate 8A) where a 4- to 5-m-thick, pink quartzarenite transitions between the two. The Random Formation generally exhibits intense folding (Plate 8B and D).

The formation has been subdivided into four facies (Butler and Greene, 1976; Hiscott, 1982) over a total thickness of 125 m. Whereas mapping at this scale was not applicable to this study, it was noted that abundant syneresis cracks (Plate 8C) and trace fossils (Plate 8E) were mutually exclusive in the fine-grained facies of the Random Formation.

ADEYTON GROUP

The Adeyton Group outcrops in three locations with the type locality (Jenness, 1963) being the smallest and most structurally complex in a fault-bounded block, at Adeytown. Other areas include two synclinal structures near the centre of the map area, and northwest to westerly dipping beds crossing Random Island from Foster's Point to Snook's Harbour and from Smith Point, north. The largest area of outcrop occupies the doubly plunging Burgoyne's Cove syncline or Burgoyne's Cove Basin, and is truncated by the Lower Lance Cove Fault. The Nut Cove syncline plunges to the southwest and is the site of the majority of slate mining in this area. A seasonal slate quarry operates out of the Nut Cove site by Hurley Slate Works Co. Inc. Red, green and grey slate and thin-bedded pink, nodular limestones are the main rock types of the Adeyton Group. The Adeyton Group in ascending order includes the Bonavista, Smith Point, Brigus and Chamberlains Brook formations in the Random Island map area.

Bonavista Formation

The Bonavista Formation (van Ingen, 1914; Hutchinson, 1962) is the basal unit of the Adeyton Group (Jenness, 1963). This formation consists of red and grey intensely cleaved shales containing light-pink limestone nodules, occurring on particular bedding planes, occasionally coalescing into distinct limestone beds (Plate 9A). This formation disconformably overlies the Random Formation and conformably underlies the Smith Point Formation. A distinctive disconformity was observed at three separate locations, east of Smith Point in Smith Sound, and east of Hickman's Harbour and west of Black Duck Cove, both in Northwest Arm. The disconformity marks a transition from nearshore coarse-grained sediments of the Random Formation to the fine-grained, quiescent sediments of the Adeyton Group. It is composed of a thin, intraformational pebble conglomerate bed overlain by a thin stromatolitic horizon that has, in places, become replaced by calcite (Plate 9B). This unit sharply grades into highly cleaved shales above. Further subdivision of the Bonavista Formation has been developed in the past (Landing and Benus, 1987; Fletcher, 2006) but is too detailed for this project.

Smith Point Formation

The Smith Point Formation is a very distinctive, richly fossiliferous pink to brick-red highly indurated limestone and dark-red shale interbeds (Plate 9D). It was first described by Walcott (1900), formally named by Hutchinson (1962) and included in the Adeyton Group by Jenness (1963). The type section is at Smith Point on the north side of Smith Sound. It also outcrops at four locations within the Burgoyne's Cove Basin, near Clifton, Tilton Head, east of Britannia and west of Petley. It conformably overlies the Bonavista Formation and conformably underlies the Brigus Formation. The Smith Point Formation is 7 m thick at the type locality and has been subdivided in the past based on fossils (Landing and Benus, 1987; Fletcher, 2006), including trilobite debris, stromatolites, oncolites (Plate 9E), and hyoliths (Schwartz, 2006).

Brigus Formation

The Brigus Formation includes all the nodular mudstones overlying the Smith Point Formation and underlying the maganiferous shale and limestone at the base of the Chamberlain's Brook Formation. Originally proposed in van Ingen's (1914) stratigraphic nomenclature, it was later revised by Hutchinson (1962) and further subdivided using trilobite assemblages (Fletcher, 2006). Prominent limestone

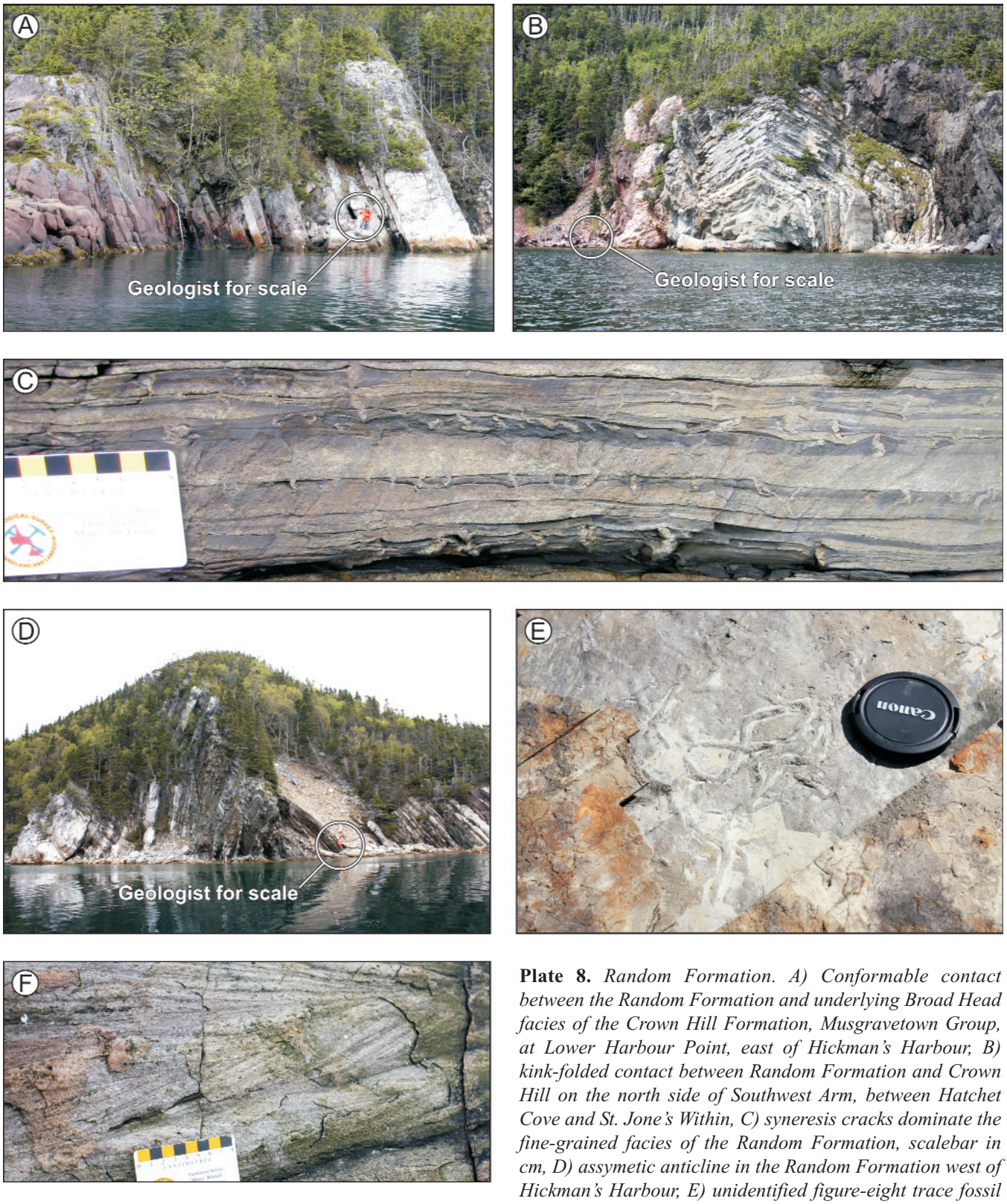

Plate 8. *Random Formation. A) Conformable contact between the Random Formation and underlying Broad Head facies of the Crown Hill Formation, Musgravetown Group, at Lower Harbour Point, east of Hickman's Harbour, B) kink-folded contact between Random Formation and Crown Hill on the north side of Southwest Arm, between Hatchet Cove and St. Jone's Within, C) syneresis cracks dominate the fine-grained facies of the Random Formation, scalebar in cm, D) assymetic anticline in the Random Formation west of Hickman's Harbour, E) unidentified figure-eight trace fossil in the Random Formation, east of Hickman's Harbour, lens cap 5.8 cm diameter, F) herring-bone crossbedding in the quartzarenites of the Random Formation, east of Hickman's Harbour, scalebar in cm.*

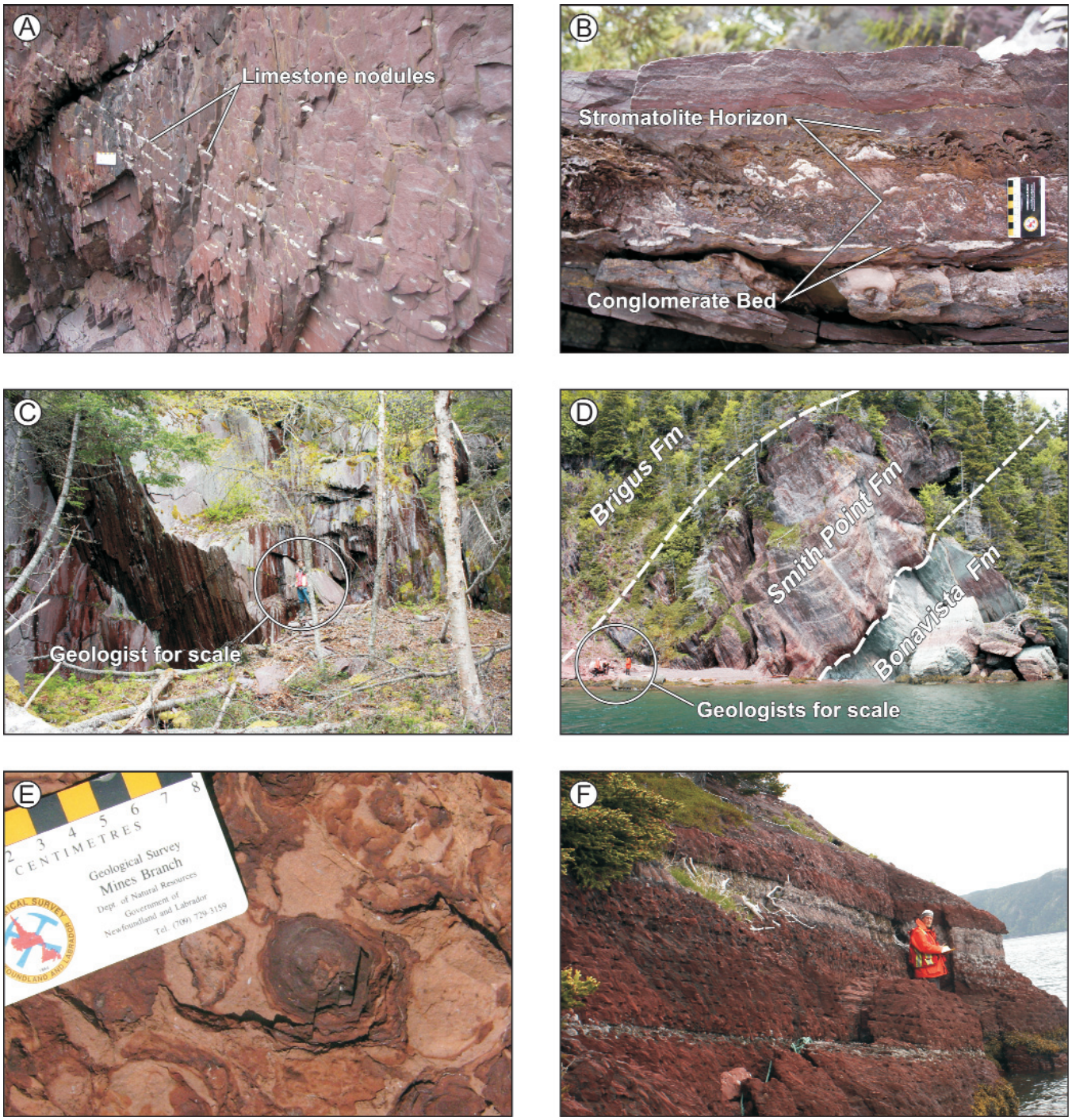

Plate 9. *Adeyton Group. A) Nodular red mudstone of the Bonavista Formation, on the eastern side of the Burgoyne's Cove Basin, north shore of Smith Sound, scalebar in cm, B) disconformity at the base of the Bonavista Formation, east of Hickman's Harbour; crossbedded sandstones are overlain by a thin intraformational shale pebble conglomerate that has been overlain by a thin stramatolitic horizon, scalebar in cm, C) the "Winter" slate quarry west of Hickman's Harbour was active during the 18th century, geologist circled for scale, D) Smith Point Formation limestone steeply dipping to the west at Tilton Head, east of Burgoyne's Cove; example of the headland forming ability of the erosion resistant Smith Point Formation, E) plan view of oncolites within the Smith Point Formation at the type location in Smith Sound, scalebar in cm, F) prominent limestone bed within the Brigus Formation, west of Burgoyne's Cove, Smith Sound.*

beds occur in the Brigus Formation west of Burgoyne's Cove, Smith Sound (Plate 9F).

Chamberlains Brook Formation

The Chamberlains Brook Formation is a calcareous dark-red mudstone sequence marking the top of the Adeyton Group, conformably underlying the Manuels River Formation of the Harcourt Group. It was originally proposed by Howell (1925) and later redefined and revised by Hutchinson (1962). The Chamberlains Brook Formation outcrops as westerly dipping beds between Elliott's Cove and Weybridge, on the north shore of Smith Sound, west of Smith Point and in the core of the Burgoyne's Cove Basin on both sides of Smith Sound. Fletcher (2006) subdivides the Chamberlains Brook Formation into six members in the Cape St. Mary's area.

HARCOURT GROUP

The Harcourt Group was originally erected by Jenness (1963) to accommodate the Cambrian and Ordovician sedimentary rocks in the Random Island map area, consisting of the Manuels River, Elliott's Cove and Clarenville formations. Whereas some dispute has existed in the past regarding the differentiation of these formations based primarily on biostratigraphy (Christie, 1950; Jenness, 1963), others suggest field mapping of distinct lithostratigraphic units may be recognized regardless of faunal content (Martin and Dean, 1981; Fletcher, 2006). The main problem with differentiating Elliott's Cove and Clarenville formations on Random Island, also noted by Martin and Dean (1981), is the intense folding and faulting, and lately, as a result of Hurricane Igor in 2010, major slumping of coastline outcrop (Plate 10E). The Elliot's Cove and Clarenville formations may be correlated with the Beckford Head and Gull Cove formations, respectively, on the Cape St. Mary's Peninsula (Fletcher, 2006).

Manuels River Formation

Hutchinson (1962) described the Manuels River Formation as mostly dark mudstone and shale, with occasional thin limestone beds, and a stratigraphic thickness of 27.5 m on Random Island. The formation was easily distinguished from the underlying Chamberlains Group of the Adeyton Group on the coastal section between Elliott's Cove and Weybridge. It crops out as a thin sliver, dipping to the northwest across Random Island, and also outcrops on the north side of Smith Sound, where it strikes northerly. Whereas no Manuels River Formation was previously mapped in the Britannia syncline area, a spectacular specimen of *Paradoxides davidis* (Salter, 1864; Plate 10A) was located in float near Porridge Cove and is presumed to not have travelled a great distance.

The Manuels River Formation consists of black to dark-brown (weathers dark-grey), thin, parallel-laminated mudstone to dark-grey thick-bedded, fissile and friable siltstone interbedded with rare thin light yellow-brown, silty limestone beds. Fossils located in the upper Manuels Cove Formation near Fosters Head, on the north shore of Northwest Arm include *Clarella venusta* (Billings, 1872; Plate 10B) and *Hydrocephalus hicksii* (Salter, 1864; Plate 10C). The white clay bed identified as the Manuels Metabentonite (Fletcher and Bruckner, 1974), and the Metabentonite Bed (Fletcher, 2006) marking the base of the Manuals River Formation, also noted by Martin and Dean (1981) during their work on Random Island, was not identified during this study. It was likely covered due to the excessive amount of rock falls and slumps occurring as a result of recent storm activity (Plate 10E).

Elliott's Cove Formation

This formation outcrops in three areas. Northwest-dipping beds outcrop across Random Island, south of Elliott's Cove, westerly dipping beds on the north side of Smith Sound, west of Harcourt and as a small southwest-plunging syncline near Gooseberry Point on the south side of Smith Sound. Silver-grey, graphitic, micaceous mudstones are interbedded with dark-grey (weathers light-brown), thin- to medium-bedded, well-indurated fine-grained sandstone and siltstone (Plate 10D). Some siltstone beds have tool marks on the basal surface along with a variety of arthropod and annelid trace fossils, including Diplocraterion, Skolithos, Planolites, Cruziana, Triptichnus pedum, and Rusophycus.

The base of the Elliott's Cove Formation was previously defined as a disconformity overlying the Manuel's River Formation based on the presence of an intraformational shale conglomerate and missing trilobite zones (Hutchinson, 1962; Poulsen and Anderson, 1975). This conglomerate bed was not observed during the current mapping project. A dark-grey fine-grained mafic sill occurs near the base of the Elliott's Cove Formation on the north side of Northwest Arm, between Elliott's Cove and Weybridge.

Clarenville Formation

The Clarenville Formation is the thickest formation within the Harcourt Group. It outcrops in the northwest part of the map area on the western extremity of Random Island, on both limbs of a northeast-plunging anticline and around the bottom of Smith Sound (Figure 2). Outcrop along the coastline is sparse due to the friable and unconsolidated character of the sedimentary rocks. Away from the coastline, outcrop is absent as erosion has infilled all water bodies creating suitable farmland. The general rock type is dark-grey to black, rusty on bedding planes, thin, parallel-laminated

Plate 10. *Harcourt Group. A)* Paradoxides davidis *(Salter, 1864) found in float between Britannia and Lower Lance Cove on the south side of Smith Sound, scalebar in cm, B)* Clarella venusta *(Billings, 1872) from the Manuels River Formation, west of Fosters Point, north side of Northwest Arm, scalebar in cm, C)* Hydrocephalus hicksii *(Salter, 1864) from the Manuels River Formation, west of Fosters Point, scalebar in cm, D) dark-grey shales interbedded with light yellow-brown siltstone and fine-grained sandstones of the Elliott's Cove Formation, southeast of Elliott's Cove, hammer in 10 cm increments, E) large slump on the north side of Northwest Arm, between Bounds Mead and the Random Island Causeway, note geologists in lower left corner for scale, F) rusty, dark-grey shales of the Clarenville Formation, northwest of Snooks Harbour, Smith Sound, note flattened concretions along one select bedding plane.*

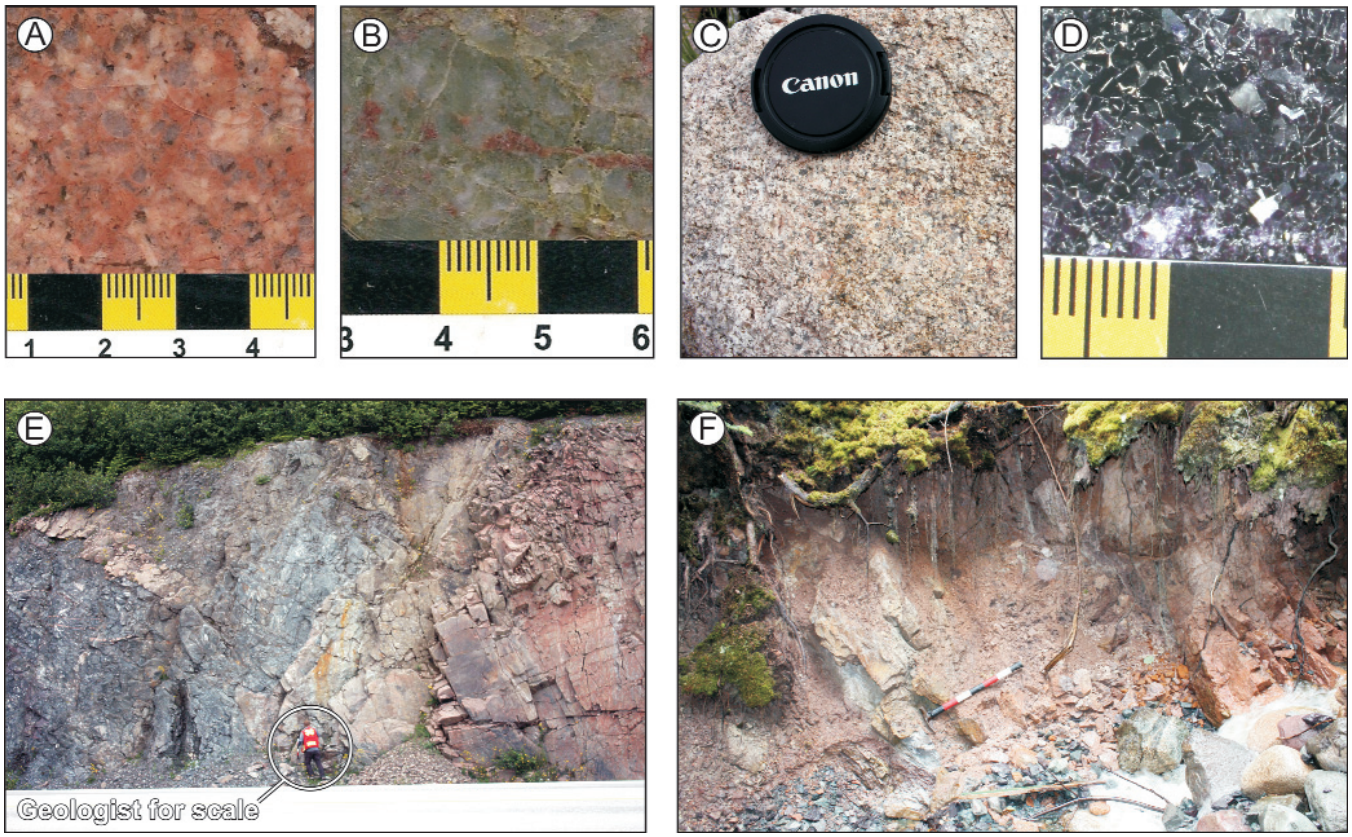

Plate 11. *Clarenville and Swift Current granites outcropping in the western margin of the map area. A) Clarenville Granite from new building development in Milton, scalebar in cm, B) rare epidotized granite located near Milton, scalebar in cm, C) white weathering of the Clarenville Granite occurs near the pluton boundaries, lens cap 5.8 cm, D) fluorite crystals in thin veins on the eastern edge of the Swift Current Granite, in an active quarry west of Northwest Brook, scalebar in cm, E) the southern boundary of the Clarenville Granite on the Trans-Canada Highway south of Clarenville, note bleached grey 4-m-thick margin of granite and granite dyke intruding country rock, F) faulted contact of Clarenville Granite with Cambrian sediments near Milton, abundant fault gouge between Random quartzites to the left (east) and Clarenville Granite to the right (west); hammer handle in 10 cm increments.*

mudstones. Development of black (weathers light yellow-brown), flattened, saucer-shaped concretions with cone-in-cone internal structures occur along some bedding planes (Plate 10F). Cleavage is intense with occasional kink folding and rare vuggy quartz occurring along joints. An Early Ordovician age for the Clarenville Formation has been assigned based on macrofossils (van Ingen, 1914; Martin and Dean, 1981).

IGNEOUS NEOPROTEROZOIC ROCKS

CLARENVILLE GRANITE

The Clarenville Granite was first mapped by Jenness (1963) as the 'Red Granite' but later renamed by Strong *et al*. (1974). It is composed of medium-grained, equigranular orange pink, biotite–hornblende granite (Plate 11A) with rare, localized, epidote alteration (Plate 11B), and a distinct bleached margin several metres thick, where it is altered with sericite (Plate 11C and E). Four small granite plutons outcrop in the Clarenville area along the periphery of the Love Cove Group volcanics to the west, and Cambrian sedimentary rocks to the east. The largest granite pluton extends from the southern edge of Clarenville to south of Bluff Point on the west side of Northwest Arm, over a distance of 2.9 km. A second body outcrops on the north side of Clarenville over 800 m, while a third body outcrops as an elongate north–south-trending unit extending through Mills Siding to Milton for a distance of 2.8 km. The fourth and most southerly plutonic body, which has previously been attributable to the Clarenville Granite (Jenness, 1963), is also the smallest and is located southwest of Adeytown.

The Love Cove volcanic rocks have a higher magnetic susceptibility than the adjacent granitic rocks allowing regional aeromagnetics to aid with mapping. Available aero-

magnetic data demonstrates a low signature for the Clarenville Granite, possibly representing a continuous pluton underneath Northwest Arm. Whereas the Lexicon of Canadian Stratigraphy (1985) and King (1988) put a Devonian age on the Clarenville Granite, faulted contacts with the Random and Bonavista formations near Milton (Plate 11F) do not substantiate this age. Geochronological analysis is warranted to determine the relationship with the compositionally similar Swift Current Granite.

SWIFT CURRENT GRANITE

The Swift Current Granite is classified as a granite–diorite (Strong *et al*., 1974); earlier authors (Hayes, 1948; Jenness, 1963) called it the Northern Bight granite. The most northeasterly of three extensions from this substantial plutonic body extends up to Lower Shoal Harbour River to the southwest of Clarenville. The Swift Current Granite extends from the southwest corner of the Random Island map area in a northerly direction where it pinches out at the Lower Shoal Harbour River. It is an orange-pink medium-grained biotite, hornblende granite and granodiorite. Minor fluorite veins (Plate 11D) were located in an active quarry to the west of Northwest Brook.

CONCLUSIONS

A diverse assemblage of rock types representing the western Avalon Zone is well exposed in the glacially carved topography of the Random Island map area (NTS 2C/04). The study area is broken down into a series of fundamental geological components, spanning the Ediacaran to the Early Ordovician. The basement component is a combination of Neoproterozoic volcanism and penecontemporaneous deep-marine sedimentation, as evidenced by the Love Cove and Connecting Point groups, respectively. Petrographic and major-element geochemistry on equivalent rocks to the north (Dec *et al*., 1992) have determined an evolved volcanic island-arc complex, developed on transitional or possibly continental crust providing a source for adjacent volcaniclastic deep-marine sedimentation of pyroclastic and epiclastic sediment. Geochronology constrains the stratigraphic position of the Love Cove Group as it has been dated in the Bonavista Bay area at 620 ± 2 Ma (O'Brien *et al.*, 1989) to precede the Connecting Point Group, dated at 610 ± 1 Ma, from a tuff near the middle of the succession (G. Dunning, unpublished data, 1990 *in* Dec *et al*., 1992).

The lithofacies associations and sedimentary structures found in the Connecting Point Group on the Random Island map area indicate a deep-marine offshore setting, prograding to a shelf/slope environment and increasing in volcanic detritus up section. The recrystallization of the siliciclastic rocks and widespread thermal affects of dyke intrusion, have removed many of the primary sedimentary structures that might identify a depositional environment. The absence of bioturbation in these thick Precambrian sequences also impedes accurate depositional environment classification. The large volume of very fine sediment in CP 1 suggests a distal component with intermittent hemipelagic sedimentation of thin, black, hematite-altered laminations. The coarser grained sedimentary rocks of CP 2, 2A and 3 indicate a more proximal shelf or slope environment. The massive, unconfined nature of the sandstones could imply a series of low volume turbidites deposited on the shelf or may represent prograding submarine fans in a confined basin (Knight and O'Brien, 1988). The tuffs cap thin, distal events, having a volcanogenic trigger related to continued Love Cove Group volcanism. The high proportion of volcaniclastic rocks found in CP 4 indicates renewed volcanism, uplift and erosion of pyroclastic and epiclastic sediments during the later stages of basin infill.

The next stage in the geological history was the emplacement of the Swift Current and Clarenville granites within the Love Cove and Connecting Point groups. A geochronological age of 577 ± 3 Ma for the Swift Current Granite (O'Brien *et* al., 1998) refutes previous suggestions that the granite is the subvolcanic equivalent of the Love Cove Group (Hussey, 1979) or a co-magmatic origin for the Swift Current Granite and the host Love Cove Group volcanic rocks (Dallmeyer *et al*., 1981).

A major angular unconformity has been observed at the contact between the Connecting Point and overlying Musgravetown Group at several locations in Bonavista Bay (Hayes 1948; O'Brien, 1987). This unconformity combined with the abundant dyke swarms found throughout the Connecting Point Group may represent a rifting episode prior to deposition of the Musgravetown Group.

A protracted period of subaerial, bimodal volcanism during the deposition of the lower Musgravetown Group as evidenced by the Bull Arm Formation, Herring Cove and Brook Point facies, may be sourced from the granitic intrusions to the west. Rhyolite from the lower Musgravetown Group has been dated at 570 +5/-2 Ma in Bonavista Bay (O'Brien *et al*, 1989).

Following Bull Arm Formation volcanism, multiple sequence stratigraphic cycles are deposited mainly as siliciclastic deposition with rare carbonate and volcanic rocks. Shallow-marine rocks of the Rocky Harbour Formation suggest a succession of tidal flats, interdistributary channels, and lower shoreface deposits. Felsic volcanism (volumetrically most insignificant) occurs prior to the transition from shallow marine to terrestrial as represented by the Herring Cove and Brook Point facies. Terrestrial siliciclastic deposi-

tion of Crown Hill Formation fluvial and alluvial environments dominates near the end of the Neoproterozoic.

Deposition of the macro-tidal Random Formation characterizes a major period of subsidence or relative sea-level rise during the Cambrian. A stromatolitic hardground unit separates the Random Formation and overlying Adeyton Group entailing a disconformable surface. The mainly deep-marine mudstones of the Adeyton Group are interspersed with periods of low clastic input allowing the deposition of distinct limestone horizons, most notably the Smith Point Formation marking the introduction of trilobites (Landing and Benus, 1987). Siliciclastic deposition continues in a deep-marine setting with the accumulation of the Harcourt Group spanning the Cambrian–Ordovician boundary and contains highly fossiliferous macrofossil intervals (Martin and Dean, 1981).

FUTURE WORK

A major objective is to compare and contrast the geological history of the western Avalon Zone with that of the Burin and Avalon peninsulas. Future work should include detailed sedimentological studies combined with a systematic geochronological analysis of the Connecting Point and Musgravetown groups utilizing the numerous volcanic horizons to establish depositional rates during Late Neoproterozoic volcanism and adjacent volcanic arc basin infill. Whereas general facies associations have been acknowledged, a more detailed sedimentological study reminiscent of Knight and O'Brien, (1988) for similar rocks to the north, would provide insight into understanding the sedimentological processes and depositional environment occurring during basin evolution of the Connecting Point Group in the Random Island map area. Major- and trace-element geochemistry should also be utilized to determine the precise association and tectonic setting of the volcanic rocks found in the map area, including; the Love Cove Group, Bull Arm Formation and the Herring Cove and Brook Point facies of the Musgravetown Group, as well as possible relationships with nearby granites. Geochronology of the granite bodies is also warranted, to clearly ascertain the relationship of the Swift Current and Clarenville granites.

ACKNOWLEDGMENTS

The author acknowledges the boat-handling skills and local knowledge of Mr. Glen Bailey and the field assistance of Dr. Christopher Phillips, Mark Colbourne, Mary Devine and Adrienne Noftall, conducted during a remarkably inclement field season. Thanks to Art King for reviewing an earlier draft of this paper.

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