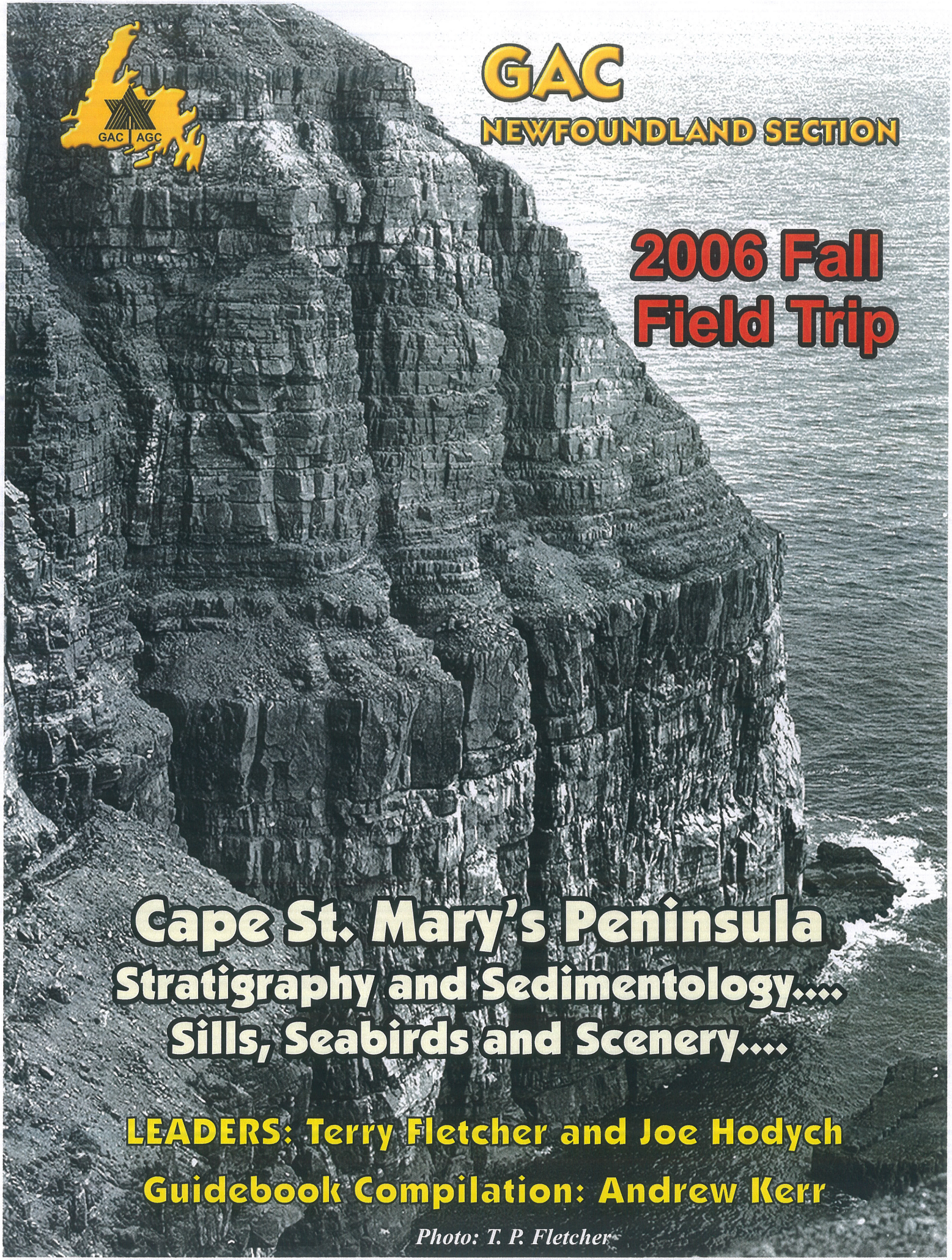
GAC
NEWFOUNDLAND SECTION
2006 Fall
Field Trip
Cape St. Mary's Peninsula
Stratigraphy and Sedimentology....
Sills, Seabirds and Scenery....
LEADERS: Terry Fletcher and Joe Hodych
Guidebook Compilation: Andrew Kerr
Photo: T. P. Fletcher

GEOLOGICAL ASSOCIATION OF CANADA NEWFOUNDLAND SECTION

2006 FALL FIELD TRIP

THE CAPE ST. MARY'S PENINSULA: STRATIGRAPHY, SEDIMENTOLOGY, SILLS, SEABIRDS AND SCENERY

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Cover: Dramatic sea cliffs near the lighthouse at Cape St. Mary's (photo by T.P. Fletcher)

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WELCOME

The Newfoundland and Labrador Section of the Geological Association of Canada welcomes all participants to the 2006 Fall Field Trip. This year's destination is the legendary Cape Shore, regarded by many as the most scenic and spectacular corner of eastern Newfoundland. It is perhaps most famous as the inspiration for one of the most beautiful and evocative of all Newfoundland folk songs - *Let me fish off Cape St. Mary's.*

This is a landscape of immense contrasts. It contains towering sea cliffs lashed by huge waves that travel all the way from South America, punctuated by tranquil protected coves fringed with green meadows. Away from the shores, gnarled and dense tuckamore forests are dwarfed by expansive tundra-like plains, vivid in shades of red, brown, orange and green. On a clear sunny day, the land is almost luminous, but the shifting fogbanks can transform it to a ghostly monochrome in just a few minutes. The brightly coloured houses of St. Bride's, Branch and Point Lance sit in fields of wildflowers, surrounded by emerald pastures. At Cape St. Mary's, the land and sea belong not to us, but to millions of seabirds and thousands of migrating whales. In addition to this great natural beauty, the Cape Shore contains interesting geological sites and many spectacular and accessible coastal sections. Highlights include the most complete sequence of Cambrian rocks in the Avalon Zone of eastern North America, Silurian mafic intrusions that provide important paleomagnetic data, and a swarm of mafic dykes that may record the birth of the modern Atlantic. The relationships exposed in its superb wave-washed coastal sections provide an excellent illustration of how careful mapping and the application of stratigraphic principles enable us to unravel local puzzles, and ultimately allow us to understand the characters and plotlines of a long and complex geological story.

ACKNOWLEDGMENTS

The Fall Field Trips of the Newfoundland Section of GAC are a long-standing tradition that is made possible by the efforts of volunteers and direct and in-kind subsidies. The 2006 field trip was supported by a generous cash donation by Husky Energy of Canada, and we wish to thank them sincerely for their support of Earth Science activities in the Province of Newfoundland and Labrador. The provision of vehicles by the Geological Survey of Newfoundland and Labrador (part of the Department of Natural Resources) is also important in making this trip possible, and is gratefully acknowledged. A subsidy for students attending the trip was provided by the Department of Earth Sciences at Memorial University, and we are also grateful for their help. Chris Pereira at the Geological Survey provided invaluable assistance in preparing and producing the field trip guide. We are grateful also for the efforts of Pat Manning and his staff at the Bird Island Resort (St. Bride's) in making our stay in the area comfortable and affordable, and for the culinary skills of Gloria at the Gannet's Nest Restaurant, where the fresh cod is as legendary as the Cape Shore fog. Portions of the guidebook for this field trip were extracted or modified from the upcoming Geological Survey Memoir on the Cape St. Mary's Peninsula, written by Terence P. Fletcher (Newfoundland and Labrador Department of Natural Resources, Geological Survey Report 2006-2). This guidebook is intended only as a simplified and abbreviated overview, and readers are referred to the memoir for full details of the geology, and complete supporting data for statements and ideas.

SAFETY INFORMATION

General Information

The Geological Association of Canada (GAC) recognizes that its field trips may involve hazards to the leaders and participants. It is the policy of the Geological Association of Canada to provide for the safety of participants during field trips, and to take every precaution, reasonable in the circumstances, to ensure that field trips are run with due regard for the safety of leaders and participants. GAC recommends steel-toed safety boots when working around road cuts, cliffs, or other locations where there is a potential hazard from falling objects. GAC will not supply safety boots to participants. Some field trip stops require sturdy hiking boots for safety. Field trip leaders are responsible for identifying any such stops, making participants aware well in advance that such footwear is required for the stop, and ensuring that participants do not go into areas for which their footwear is inadequate for safety. Field trip leaders should notify participants if some stops will require waterproof footwear.

Field trip participants are responsible for acting in a manner that is safe for themselves and their co-participants. This responsibility includes using personal protective equipment (PPE) when necessary (when recommended by the field trip leader or upon personal identification of a hazard requiring PPE use). It also includes informing the field trip leaders of any matters of which they have knowledge that may affect their health and safety or that of co-participants. Field Trip participants should pay close attention to instructions from the trip leaders and GAC representatives at all field trip stops. Specific dangers and precautions will be reiterated at individual localities.

Specific Hazards

Most of the stops on this field trip are in coastal localities. Access to the coastal sections normally requires short hikes, in some cases over rough, stony or wet terrain. This field trip involves several hikes, of which the longest is about 5 km. Participants should be in good physical condition and accustomed to exercise. The coastal sections contain saltwater pools, seaweed, mud and other wet areas; in some cases it may be necessary to cross brooks or rivers. There is a strong possibility that participants will get their feet wet, and we recommend waterproof footwear. We also recommend footwear that provides sturdy ankle support, as localities may also involve traversing across beach boulders or uneven rock surfaces. The trip involves crossing two rivers, which may be difficult if water levels are high; we recommend bringing an old pair of sneakers for wading these if necessary. On some of the coastal sections that have bouldery or weed-covered sections, participants may find a hiking stick a useful aid in walking safely.

Coastal localities present some specific hazards, and participants MUST behave appropriately for the safety of all. The high sea cliffs around Cape St. Mary's are extremely dangerous, and falls at these localities would almost certainly be fatal. Participants must stay clear of the cliff edges at all times, and stay on the marked walking trails. The Cape is famous for its impenetrable fog, and it is critical that the field trip group remain together under such conditions. Coastal

sections elsewhere lie below cliff faces, and participants must be aware of the constant danger from falling debris. Please stay away from any overhanging cliffs or steep faces, and do not hammer any locations immediately beneath the cliffs. In all coastal localities, participants must keep a safe distance from the ocean, and be aware of the magnitude and reach of ocean waves. Participants should be aware that unusually large "freak" waves present a very real hazard in some areas. If you are swept off the rocks into the ocean, your chances of survival are negligible. If possible, stay on dry sections of outcrops that lack any seaweed or algal deposits, and stay well back from the open water. Remember that wave-washed surfaces may be slippery and treacherous, and avoid any area where there is even a slight possibility of falling into the water. If it is necessary to ascend from the shoreline, avoid unconsolidated material, and be aware that other participants may be below you. Take care descending to the shoreline from above.

Weather is unpredictable in this area and participants should be prepared for a wide range of temperatures and conditions. Always take suitable clothing. A rain suit, sweater, sturdy footwear are essential at almost any time of the year.

Subsequent sections of this guidebook contain the stop descriptions and outcrop information for the field trip. In addition to the general precautions and hazards noted above, the introductions for specific localities make note of specific safety concerns such as traffic, water, cliffs or loose ground. Field trip participants should read these cautions carefully and take appropriate precautions for their own safety and the safety of others.

OVERVIEW OF FIELD TRIP

This two and a half day field trip is intended to provide participants with an overview of the geology of the Cape St. Mary's Peninsula, which is the subject of an upcoming Geological Survey Memoir and a new 1:50,000-scale geological map. The area contains a variety of rock types, but is dominated by Late Precambrian sedimentary and volcanic rocks of the Musgravetown Group. However, the "Cape Shore" is best-known for its well-preserved and complete sequence of Cambrian sedimentary rocks, which locally includes some mafic volcanic and pyroclastic rocks. The Cambrian sections are considered to be of international significance as they contain trilobite faunas that are important in the correlation of different Cambrian faunal realms. Post-Cambrian rocks in the area are of limited areal extent, but are also of great importance. Silurian mafic sills of the Point Lance area are the only igneous rocks of this age known in the Avalon Zone of Newfoundland, and they provide important paleomagnetic constraints on the closure of the Early Paleozoic Iapetus Ocean. There are also many mafic dykes that cut the Precambrian and Cambrian rocks, and postdate regional folding. The ages of these dykes are unknown, but they could be as young as Triassic, i.e., they may be related to the development of the modern Atlantic Ocean.

Cape St. Mary's is a truly famous locality immortalized in one of our best-known folk songs, and it receives many thousands of visitors each year. Tourists are drawn by the immense seabird colonies, which are largest in the North Atlantic region, and by the spectacular coastal scenery. The vivid, tundra-like barrens and the towering, stratified sea cliffs create a desolate, elemental landscape that makes human visitors feel very small and insignificant. They contrast with the "snug green coves", with their emerald pastures, sandy beaches and brightly-coloured houses surrounded by wild roses. A visit to the seabird colonies will form part of the field trip, and we hope that the famous Cape Shore fog will lift long enough for us to enjoy these memorable landscapes.

Following departure on the afternoon of Friday 29th September, the field trip group will drive to St. Mary's Bay and visit coastal outcrops near the mouth of the Red Head River and at Beckford Head, near Branch. These provide a general introduction to the character of Cambrian sedimentary rocks of the Adeytown and Harcourt groups. The excursion will start early on the morning of Saturday 30th September in order to visit classic Early and Middle Cambrian sections at Branch Cove whilst the tide remains low. Later on Saturday, the field trip group will visit Late Cambrian sedimentary rocks and Silurian igneous rocks at Point Lance, and then conclude with an examination of the Cambrian rocks in the St. Bride's area. We will also examine late diabase dykes, barite veins and areas of structural complexity. This comparison will illustrate contrasts in stratigraphy from east to west. Sunday 1st October will commence with examination of Late Precambrian (Ediacaran) sedimentary rocks in the Cape St. Mary's area, which will be followed by a lunchtime visit to the famous Bird Sanctuary. On the return trip to St. John's, we will visit interesting mafic dykes at Patrick's Cove and, if time permits, hike into the spectacular gorges at Cataracts Provincial Park, near Colinet. Note that the agenda and itinerary is in large dependent upon weather and tides, and we may thus have to adjust the ordering of stops or even switch Day 2 and Day 3 in order to accommodate these factors. We will obviously try to visit the bird sanctuaries under the best possible weather conditions.

AN OVERVIEW OF THE GEOLOGY OF THE CAPE ST. MARY'S PENINSULA

This section of the guidebook provides essential geological background information for the area visited by the field trip, with reference to simplified geological maps, cross-sections and stratigraphic charts. It is not intended to provide a detailed account of all of the rock types present in the area, nor does it provide complete discussion and interpretation. The text in this section is mostly simplified and modified from a forthcoming Geological Survey Memoir (Fletcher, 2006), and readers with an interest in specific details or issues are referred to this publication. Fletcher (2006) also revises some earlier nomenclature and interpretations. This guidebook does not attempt to explain or substantiate such revisions and changes in detail, and it should not be referred to in this context.

Historical Background

The Cape St. Mary's Peninsula lies relatively close to St. John's, but it did not receive a great deal of attention from early investigators of Newfoundland geology. However, the Branch Cove section in St. Mary's Bay actually yielded the first diagnostic Cambrian fossil recorded from the island, namely *Paradoxides* (*Eccaparadoxides*) *bennetti* (Salter, 1859). Alexander Murray visited the southwest Avalon Peninsula in 1868, and postulated the existence of a regional anticlinal structure, which exposed older sedimentary rocks in its core (*in* Murray and Howley, 1881). Murray also suggested that there were two "troughs" (i.e., synclines) that exposed younger fossiliferous rocks on the shores of Placentia Bay and St. Mary's Bay, respectively. This pattern is certainly evident in all subsequent geological maps of the area.

Later investigators of Cambrian rocks in Newfoundland concentrated on the more accessible sections exposed around Conception Bay and Trinity bays, and these came to be regarded as the classic Cambrian sections of eastern North America. The more complete sequences exposed on the Cape St. Mary's Peninsula remained largely unexamined. It was not until the work of Hutchinson (1953, 1962) that a general outline of the Cape St. Mary's Cambrian sequence and its main exposures was presented. McCartney (1967) provided further details of the area in a GSC memoir for the Whitbourne map-area, based largely upon work conducted through Harvard University between 1954 and 1957. In 1959, T. P. Fletcher mapped the region south of Angels Cove and Red Head, and discovered the important trilobite fauna in Branch Cove, and the layered sills in the Gull Cove - Point Lance region. Greene (1962a, b) later mapped the Cambrian rocks of the Point Lance and Branch areas. The regional geology of the Avalon Peninsula was integrated in the 1:250,000 scale map published by King (1988), for which details of the Cape St. Mary's area were compiled largely from the work of Fletcher (1972; see below).

T.P. Fletcher continued work in the area between 1963 and 1966, with emphasis on the trilobite faunas of the Branch and Redland Cove areas. This work recognized that the fossiliferous sequence was unbroken, and highlighted the interesting and unusual trilobites. The study eventually led to a Ph.D. Thesis on the Cambrian rocks of the area (Fletcher, 1972), that eventually led to the current geological map (Fletcher, 2006).

Hodych and Patzold (1980) and Hodych and Buchan (1994, 1998) established the Silurian age and palaeomagnetic features of mafic sills within the Cambrian sequence near Point Lance. Greenough (1984) and Greenough and Papezik (1985, 1986) conducted petrological and geochemical studies of the Silurian mafic sills, and also of mafic volcanic rocks within the Cambrian sequence. Greenough et al. (1993) subsequently published a precise U-Pb baddellyite age of 441 +/- 2 Ma from the former; this was the first use of the mineral baddellyite for such dating.

Between 1973 and 2004, T. P. Fletcher continued intermittent fieldwork on the fossiliferous Cambrian rocks, with emphasis on trilobite taxonomy, faunal correlation and subdivisions of the Cambrian System. Such information has highlighted the global significance of the exposures in Branch Cove and Redland Cove on St. Mary's Bay (Fletcher, 1999; 2001; 2003; 2005; Fletcher *et al.*, 2005; Robison *et al.*, 1977). A forthcoming Geological Survey Memoir (Fletcher, 2006) provides an updated geological map of the peninsula and detailed descriptions of all formations and units. The memoir also contains complete descriptions of the trilobite faunas and discussion of their significance in a wider context.

The area has been visited as part of several previous field trips, but has never been the focus of a dedicated excursion. Previous field trip guides include King et al. (1974) from a national GAC-MAC conference, with stop descriptions by T. P. Fletcher. A field trip also visited the area in 1997 as part of a wider conference aimed at Avalonian stratigraphy throughout eastern Canada (Landing and Westrop, 1997). The Silurian and younger igneous rocks of the area were the subject of a short field excursion in 2001, associated with a national GAC-MAC-CSPG conference (Greenough and Hodych, 2001). These guides have also been used as sources for this guidebook, although it should be noted that interpretations offered by Landing and Westrop (1997) differ in some respects from those presented here.

Regional Geology

The Cape St. Mary's Peninsula forms part of the Avalon Zone of the Appalachian orogenic belt. The Avalon Zone comprises late Precambrian and early Paleozoic rocks that lie on the eastern margin of the Appalachian orogenic belt in Newfoundland, Nova Scotia, New Brunswick and in parts of the eastern U.S.A. (O'Brien et al., 1983; 1996, Figure 1).

The Avalon Zone of eastern Newfoundland is largely confined to the Avalon and Burin Peninsulas and adjacent areas. The geological record of the Avalon Zone is largely late Precambrian ("Pan-African"; e.g., O'Brien et al., 1983, 1996) and represents the period between the Neoproterozoic Grenvillian Orogeny and the earliest events recorded in the development of the Appalachian-Caledonian Orogen. Parts of the Avalon Zone stratigraphy, including rocks in the field trip area, are now assigned to the "Ediacaran" period, which precedes the Cambrian in the geological time scale (e.g., Knoll et al., 2006). The Avalon Zone has a complicated Precambrian stratigraphy, including abundant felsic volcanic sequences, and it was intruded by numerous late Precambrian granitoid plutons. In most areas, a well-developed sub-Cambrian unconformity separates these older rocks from a Paleozoic cover sequence, which includes Cambrian and Early Ordovician rocks, but likely extends into the Silurian in offshore areas. The

Paleozoic cover is faunally distinct from that of western Newfoundland, and is dominated by siliciclastic rocks, rather than carbonate sequences.

The Precambrian magmatic history of the Avalon Zone is complex, including major pulses at ~ 760 Ma, 680 Ma, 635-600 Ma and 575-560 Ma (e.g., O'Brien et al., 1996). Early events likely record rifting and amalgamation of individual subterranes, and the various components are believed to have been assembled into a composite entity by ~ 635 Ma, and then subjected to continued compressional events and magmatic activity. The youngest sedimentary rocks comprise a shallowing-upward sequence that records the filling of marine basins and subsequently fluvial sedimentation. The Musgravetown Group, which underlies much of the field trip area, represents this period in the evolution of the Avalon Zone.

The geology of the Cape St. Mary's Peninsula is illustrated in Figure 2 (from Fletcher, 2006). Table 1 summarizes the major groupings of rocks according to their age. Broadly speaking, the core of the peninsula is formed by Late Precambrian (Ediacaran) rocks of the Musgravetown Group (McCartney, 1967; King, 1988). These include volcanic rocks, which form a high interior plateau, and several younger sedimentary formations of both marine and nonmarine origins. Regionally, these older rocks form the cores of two large anticlinal structures, which have NNE-SSW trending axes, and are doubly-plunging. On the coastlines of Placentia Bay and St. Mary's Bay, associated synclinal structures reveal younger rocks of early Paleozoic age; the largest such area lies between Branch and Point Lance (Figure 2). The structure of the area is illustrated by a simplified cross-section (Figure 3; from Fletcher, 2006).

The Paleozoic rocks are mostly of Cambrian age and are assigned to the Adeytown Group and the Harcourt Group (Jenness, 1963; King, 1988). The Adeytown Group is separated from the sedimentary rocks of the Musgravetown Group by an unconformity, but there is no profound angular discordance between them. Complexities in the stratigraphy of the Cambrian rocks suggest that there are also unconformities and/or disconformities *within* the sequence. There are also some local examples of mafic volcanic and pyroclastic rocks within the upper part of the Adeytown Group. The Harcourt Group conformably overlies the Adeytown Group and forms the core of the large synclinal structure in the Branch and Point Lance areas. It also contains local examples of mafic volcanic and pyroclastic rocks.

Numerous mafic sills, locally showing compositional layering, occur mostly within the youngest rocks of the Harcourt Group in the Point Lance area, but also intrude older formations. These sills are largely conformable in character and their emplacement predates the regional folding that defines the map pattern (Figure 2). Geochronological investigations (Greenough et al., 1993) indicate that the mafic sills are of Silurian age (441 +/- 2 Ma). The youngest igneous rocks in the area are mafic dykes that have a broadly NW-SE orientation. These cut all of the sedimentary formations, and presumably also cut the Silurian mafic sills, although this relationship has not been observed. The dykes postdate the regional folding of Silurian and older units; they are thus considered to be Devonian or younger.

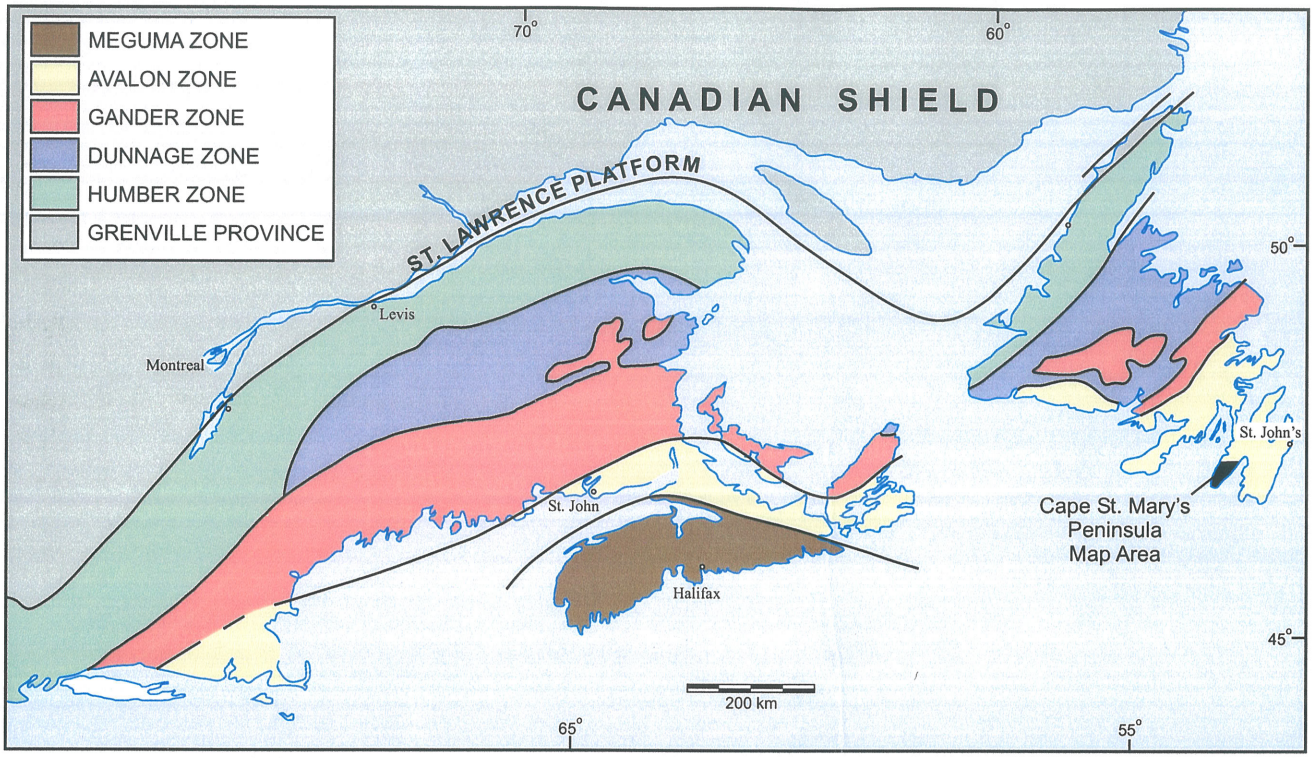

Figure 1. The location of the Cape St. Mary's Peninsula in the context of tectonostratigraphic zones within the Appalachian Orogen of Eastern Canada. From Fletcher (2006); Zones from Williams (1979).

Age	*Stratigraphic Name(s)*	*Rock Type(s)*
PLEISTOCENE		Tills, gravel, sand, etc.
DEVONIAN or TRIASSIC ? *Intrusive contact*	ST. MARY'S DYKES	Diabase.
SILURIAN (~441 Ma) *Intrusive contact*	POINT LANCE SILLS	Gabbro and diabase.
MIDDLE TO UPPER CAMBRIAN	HARCOURT GROUP (Manuels Riv., Beckford Head and Gull Cove formations)	Black shales, siltstones, and sandstones, minor mafic volcanic and pyroclastic rocks.
EARLY AND MIDDLE CAMBRIAN *Unconformity*	ADEYTOWN GROUP (Random, Bonavista, Smith Point, Brigus and Chamber-lains Brook formations)	Quartzites and sandstones, overlain by shallow-water red and green mudstones and minor carbonate rocks. Thin mafic volcanics at top.
PRECAMBRIAN (EDIACARAN)	MUSGRAVETOWN GROUP (Bull Arm, Big Head, Maturin Ponds, Heart's Content and Crown Hill formations)	Volcanic rocks at the base, overlain by coarsening-upward sequence of siltstones, sandstones, arkoses and conglomerates.

Table 1. Major geological formations and units in the Cape St. Mary's Peninsula area.

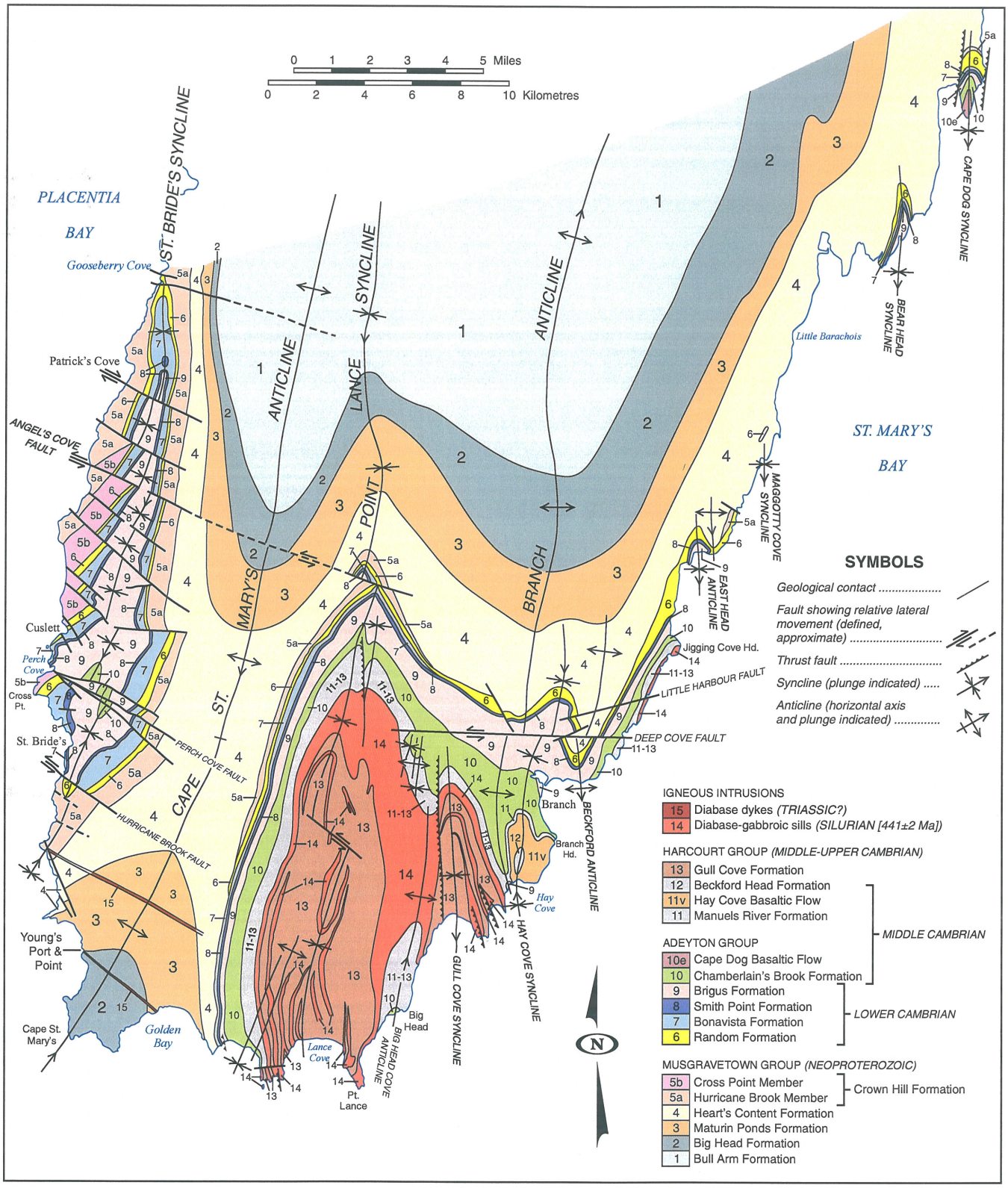

Figure 2. *A simplified geological map of the Cape St. Mary's Peninsula. From Fletcher (2006).*

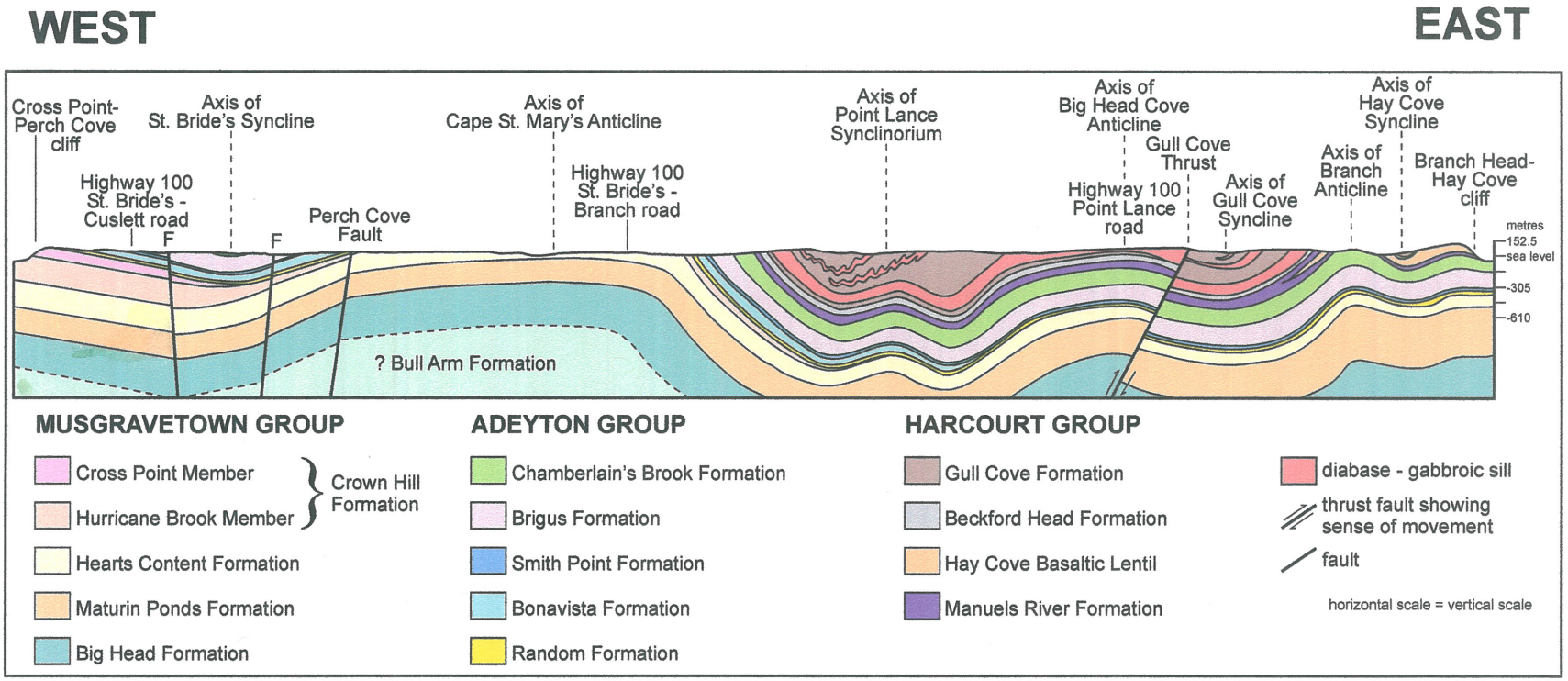

Figure 3: Approximately East-West cross section through the Cape St. Mary's Peninsula, from Cross Point to Hay Cove. For location of section, see Figure 2. From Fletcher (2006)

Precambrian (Ediacaran) Rocks - The Musgravetown Group

The Late Precambrian (Ediacaran) Musgravetown Group occupies most of the peninsula, but is mainly exposed in inland areas; the coastal sections in the Cape St. Mary's area are largely inaccessible due to high sea cliffs. The lithostratigraphy of the Musgravetown Group is illustrated in Figure 4 (from Fletcher, 2006). In the Cape St. Mary's area, it is divided into five formations; Fletcher (2006; Figure 4) defines additional subdivisions at the member level, but these are not discussed here.

The lowermost formation is the *Bull Arm Formation*, consisting of mafic and felsic flows, breccias and pyroclastic rocks interbedded with tuffaceous arkose, siltstone and conglomerate. Only the upper part of this formation is exposed on the high interior plateau of the peninsula. The Bull Arm Formation is overlain by the *Big Head Formation*, best exposed in the high cliffs around Cape St. Mary's. This formation is dominated by arkosic sandstones, with lesser siltstone and mudstone. The Big Head Formation is overlain by the *Maturin Ponds Formation*, which consists of redbed arkoses, siltstones and local conglomerates. These were likely deposited in shallow water and/or high-energy fluvial environments. Sedimentary structures in these rocks will be examined during the field trip. The Maturin Ponds Formation is overlain by the *Heart's Content Formation*, consisting of arkoses, siltstones and quartz-pebble conglomerates. The uppermost formation is the *Crown Hill Formation*, which consists of red siltstone and arkose, overlain by red conglomerates. The Crown Hill Formation will be visited during the field trip at Patrick's Cove and at Cross Point, near St. Bride's.

Cambrian Sedimentary Rocks - The Adeytown Group

The stratigraphy of the Adeytown Group in the field trip area is illustrated in Figure 5 (from Fletcher, 2006). The Adeytown Group is an Early and Middle Cambrian shelf assemblage of weakly tectonized quartz arenites and red, purple and green, carbonate-bearing mudstones. It lies above the Ediacaran–Cambrian sedimentary rocks of the Fortune Group (not exposed in this area) and below the Late Cambrian, deeper-water sedimentary rocks of the Harcourt Group (see descriptions below). The base of the Adeytown Group is generally transgressive and it commonly rests unconformably upon an eroded sequence of Ediacaran rocks. Its upper limit is drawn at the base of the conformable *Metabentonite Bed* (a whitish clay unit) that marks the base of black shaly mudstones assigned to the Manuels River Formation of the Harcourt Group.

The Adeytown Group is divided into five formations (Figure 5). Fletcher (2006) provides further subdivision at the member level (also shown in Figure 5), but these are not discussed here in the interests of brevity. It contains two important marker horizons. The lowermost is the *Smith Point Formation*, which comprises distinctive stromatolitic limestones. The upper marker is a prominent manganiferous interval located at the base of the *Chamberlains Brook Formation* (Figure 5). The five formations are described in detail by Fletcher (2006), with emphasis upon detailed stratigraphy and paleontology; the following is a summary only.

The lowermost formation is the *Random Formation*. This consists of white quartz arenites interbedded with grey-green sandstones and siltstones. Conglomerate units containing

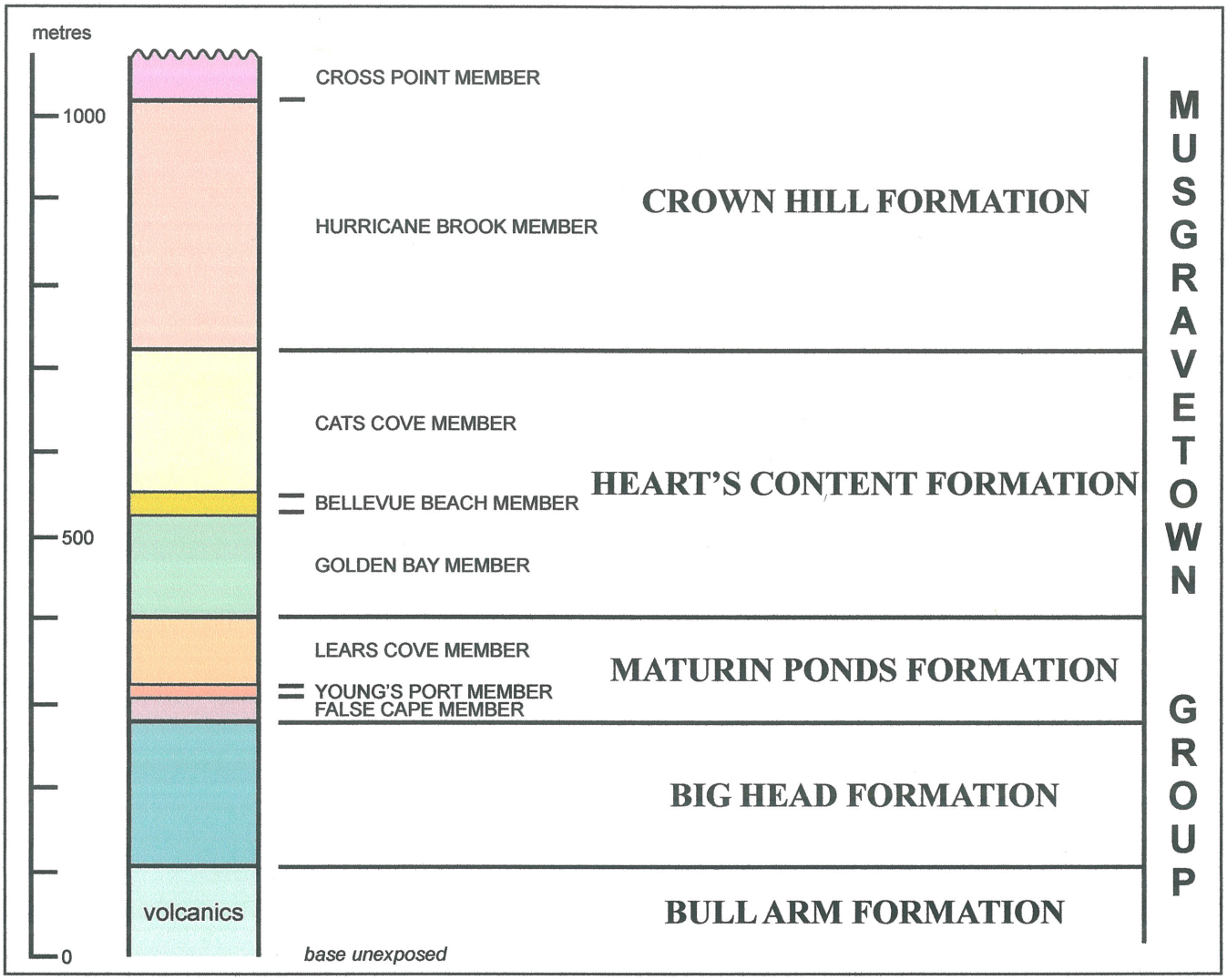

Figure 4. Lithostratigraphy of the Musgravetown Group in the Cape St. Mary's Peninsula Area.
From Fletcher (2006)

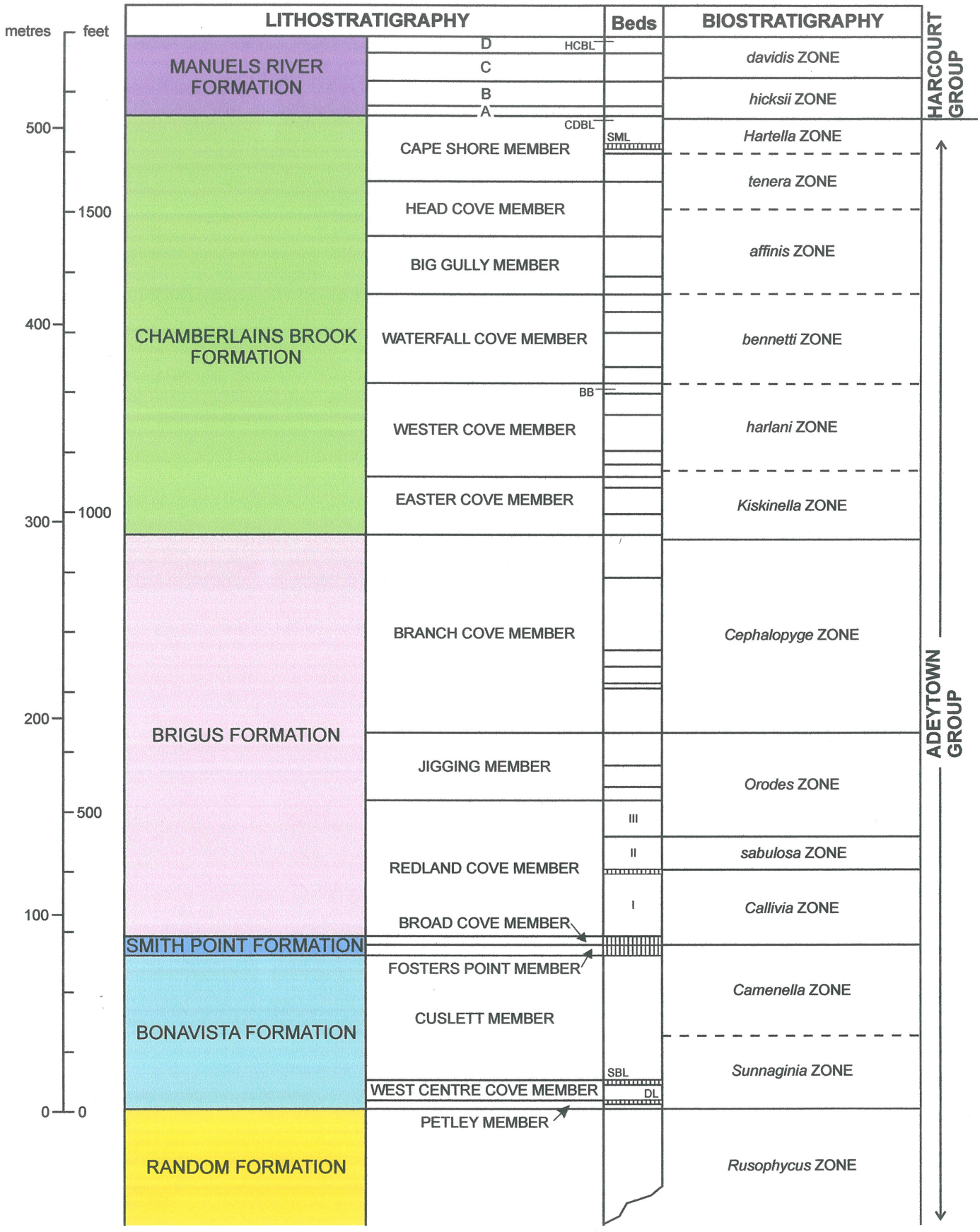

Figure 5. Lithostratigraphy and biostratigraphy of the Cambrian Adeytown Group and lowermost Harcourt Group
After Fletcher (2006).

clasts of rhyolite, basalt, chert and jasper occur at the base of the formation. The base of the Random Formation is an unconformity, as it transgresses various members of the Heart's Content and Crown Hill formations (see above). The top of the Random Formation is also transgressed by younger Adeytown Group formations, such that it is locally absent. In the west of the area, around St. Bride's, the Random Formation is overlain by the *Bonavista Formation*. This formation consists of dominantly red mudstones interbedded with green and purple mudstones and some nodular limestones. The Bonavista Formation is absent in the east of the area. The *Smith Point Formation* transgresses the Bonavista Formation in the west to rest directly on the Random Formation in the east. The Smith Point Formation is a distinctive marker consisting of pink to red stromatolitic limestones, interbedded with dark red, locally manganiferous mudstones. It represents an interval of geological time when the supply of clastic material was considerably restricted during a period of lowered sea level. The relationships with underlying formations suggest that the base of the Smith Point Formation is conformable in the west, but disconformable in the east. In all areas, the Smith Point Formation is overlain by the *Brigus Formation*. This formation is dominated by red mudstones containing nodular limestone horizons, interbedded with green and purple mudstones; Fletcher (2006) subdivides it into three members, based on subtle contrasts in lithology and faunal variations (Figure 5). The uppermost formation in the Adeytown Group is the *Chamberlains Brook Formation*, which is extensively subdivided at the member level by Fletcher (2006). This formation consists mostly of calcareous dark red and pale olive-green mudstones; volcanic rocks occur within the upper part of the formation at Cape Dog (at the northeastern extremity of Figure 4). The Brigus and Chamberlains Brook formations are the most fossiliferous of the Cambrian formations in the area; the faunas are described and discussed in detail by Fletcher (2006). All of the formations within the Adeytown Group will be visited on Days 1 and 2 of the field trip, and representative examples of the rock types in each will be examined. We will also see the stratigraphic complexities discussed above.

Cambrian Sedimentary Rocks - The Harcourt Group

The Harcourt Group (Jenness, 1963) consists of dark grey and black shales, siltstones and sandstones that overlie the predominantly red and green mudstones of the Adeytown Group. The change in lithology represents a drastic change in the sedimentary environment from a shallow-water oxidizing environment to a deep-water reducing environment. In the field trip area, the Harcourt Group is represented by three formations. The lowermost is the *Manuels River Formation*, which is best known in the Conception Bay South area, where it contains prolific fossil localities. This formation consists of black sulphurous mudstone and shale, interbedded with thin shelly limestone horizons. In the field trip area, the upper part of the formation includes submarine volcanic rocks, termed the Hay Cove Basaltic Flow, exposed on a high clifftop south of the village of Branch (Figure 2). The volcanic rocks include waterlain tuffs and hyaloclastite breccias, and some thin pillow lava units. The flows have major and trace element characteristics indicating that they are alkaline, rather than tholeiitic, and likely associated with a tensional tectonic regime (Greenough and Papezik, 1985). A thin green tuff unit within the formation at Beckford Head represents the lateral equivalent of these volcanic rocks, which were of local extent only. The Manuels River Formation is overlain by the *Beckford Head Formation*, which is

dominated by thick-bedded, pale grey, blocky siltstones, containing sporadic calcareous nodules. This formation contrasts with the shale-dominated sequences of the formations above and below it, and is relatively unfossiliferous. The uppermost formation in the Harcourt Group in this area is the *Gull Cove Formation*, which consists of dark grey to black shaly mudstones and interbedded sandstones. This formation is intruded by numerous mafic sills, and it seems likely that it was the preferred site for magma emplacement, because of its lithological character. The formation is poorly fossiliferous. All three formations in the Harcourt Group will be examined on the field trip.

Silurian Igneous Rocks

The most abundant igneous rocks on the Cape St. Mary's Peninsula are the mafic sills that mostly intrude the Gull Cove Formation of the Harcourt Group, and also intrude parts of the underlying Beckford Head Formation. However, thin pretectonic sills are also present locally elsewhere in the Musgravetown Group and the Adeytown Group, and are presumed to be correlative. The sills have commonly been called the "Cape St. Mary's Sills", although they do not actually occur at that location; the best exposures are around Point Lance (Figure 2). The outcrop pattern is complex, and individual sills are generally not continuous, implying that they wedge out along strike; some sills transgress individual beds or groups of beds, indicating that their contacts are not strictly conformable. The sills are described by Fletcher (1972, 2006), Greenough and Papezik (1986) and by Greenough and Hodych (2001). They consist of diabase and gabbro, and they exhibit considerable variation in texture; the thicker sills are compositionally layered. Cumulate layers containing olivine are present locally at the base of one sill, and geochemical evidence suggests that olivine fractionation was important in generating compositional variation. The crystallization of the sills led to residual enriched magmas that crystallized as leucocratic granophyric segregations, commonly in the upper parts of the larger bodies. Geochemical studies of the sills indicate that they have characteristics transitional between those found in alkali basalts and those in tholeiites, making assignation of tectonic environments problematic. It also seems that igneous fractionation trends were masked by volatile transport of some elements (Greenough and Papezik, 1986). The age of the sills was determined precisely by U-Pb dating of the mineral baddeleyite (ZrO_2), which indicated an age of 441 +/- 2 Ma (Greenough et al., 1993). This was the first use of baddeleyite for precise dating in terrestrial rocks.

As the only Silurian igneous rocks known in the Newfoundland Avalon Zone, these mafic sills provide important paleomagnetic information. Hodych and Buchan (1998) demonstrated that the remnant magnetization in the sills predated regional folding, and was thus likely acquired at the time of emplacement and crystallization. The results indicate a paleolatitude of 32° +/- 8° south for western Avalonia at 441 Ma. Comparison with the paleomagnetism of the 460 Ma Dunn Point volcanics shows that Avalonia had been moving northwards towards a relatively stationary Laurentia through the upper Ordovician (Hamilton and Murphy, 2004). Comparison with results from contemporaneous rocks in Laurentia suggest that the Iapetus Ocean at ~ 440 Ma had a maximum width of some 1000 km, assuming that it closed orthogonally (Hodych and Buchan, 1998). The results are shown in Figure 6.

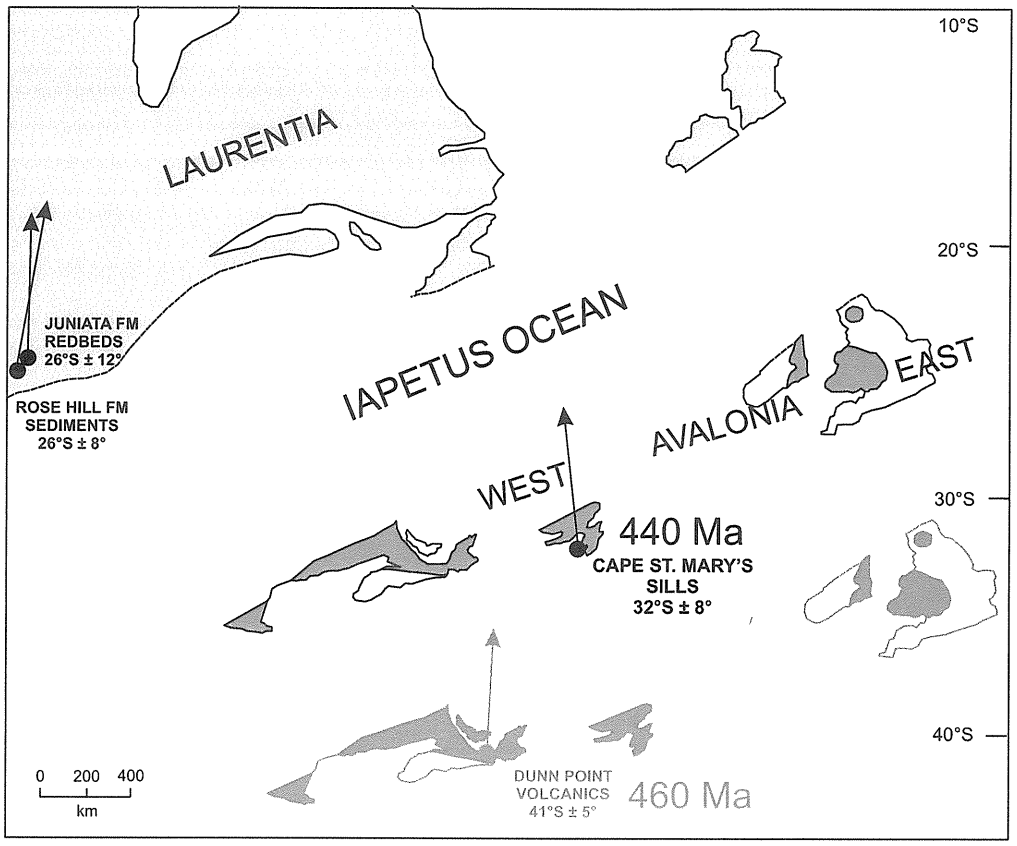

Figure 6. Paleogeographic reconstruction for ~ 460 to 440 Ma based on paleomagnetism of the Point Lance sills and the assumption of orthogonal closure of the Iapetus Ocean (after Hodych and Buchan, 1998). North arrows and paleomagnetically determined latitudes are shown. The diagram also shows the revised data for the Dunn Point volcanics of Nova Scotia (see text).

Laurentia appears lightly stippled with northern Britain and Ireland in their pre-Atlantic-opening positions compared to North America. Darkly stippled areas include west Avalonia (Avalon Peninsula, and Nova Scotia to Boston) and east Avalonia (southern Britain and Ireland, and are plotted in their pre-Atlantic-opening positions relative to one another.

Diagram and caption modified after Greenough and Hodych (2001).

The Silurian mafic sills will be examined in the Lance Cove area.

Devonian or Younger Mafic Dykes

Mafic dykes having a generally NW-SE orientation occur throughout the Cape St. Mary's Peninsula, and are associated with the wider system of joints and faults that cuts across the entire folded succession of Precambrian to Silurian age (Figure 2). They are best exposed on the shoreline of Placentia Bay (Figure 2). The dykes are described by Fletcher (1972, 2006), Greenough (1984) and Greenough and Hodych (2001). Most of the dykes are fine-grained and equigranular, but some examples contain plagioclase phenocrysts. One dyke at Patrick's Cove contains large plagioclase megacrysts and crystal aggregates that were presumably derived from a deeper magma chamber. The primary mafic mineralogy is only rarely preserved. Trace element compositions suggest that the dykes have continental tholeiite to mildly alkaline characteristics. Greenough and Hodych (2001) note that some dykes are more altered than others and suggest that there may be more than one generation amongst them.

The age(s) of these dykes is (are) not yet constrained by radiometric dating. A Devonian age is possible (Greenough and Hodych, 2001), but some of the dykes could be much younger, as Triassic and Jurassic mafic intrusions occur elsewhere within the Avalon Zone of eastern Canada (e.g., Papezik et al., 1975; Hodych and Hayatsu, 1980). Mafic dykes will be observed at Patrick's Cove, and at several other localities where they cut Cambrian sedimentary rocks of the Adeytown Group.

Structural History

The Cape St. Mary's Peninsula has not yet been the subject of detailed structural studies. The regional structural architecture of the area is dominated by the map-scale folds that affect rocks of Late Precambrian (Ediacaran), Cambrian and Silurian age (Figure 2). These folds, and related structures, are believed to have developed during the Devonian Acadian Orogeny, which affected much of the Avalon Peninsula. Most of the faults in the area likely represent a system of tear faults related to the stresses developed in this main period of folding. Small thrust faults are present in some of the tighter synclines in the Cambrian rocks, although the amounts of movement along these faults appear to be minor. The most prominent example is the Gull Cove Thrust, west of Branch (Figure 3). The relatively incompetent and thinly-bedded rock units of the Cambrian sequence appear to have been more conducive to the development of these structural complications. The thrust faults are oriented subparallel to the fold axes, and they dip to the west. The single cleavage developed throughout the area also appears to be axial-planar to the regional fold structures.

Other considerations indicate that the history of the area is more complex than it at first appears. There is a low-angle unconformity at the base of the Random Formation that indicates at least some deformation and uplift of the Late Precambrian (Ediacaran) rocks prior to deposition of the Cambrian sequence. There is also an unconformity at the base of the Smith Point Formation in the east of the area, which hints at disturbances during the Cambrian. Fletcher

(2006) also suggests sequence breaks at higher stratigraphic levels within the Adeytown and Harcourt Groups. However, it does not appear that these events caused any significant folding or the development of penetrative cleavages.

Trilobite Faunas and Their Significance

Fletcher (1972; 2006) provides extensive information on the trilobite faunas of the Cape St. Mary's Peninsula and their significance. A brief summary of the main points is given here.

Most trilobites of the Avalon Zone are characteristic of the "Acado-Baltic" faunal realm, i.e., they are associated with a suite of taxa that dwelt on this specific continental shelf, inferred to have been at fairly high paleolatitudes. The main variations in fossil assemblages are due to different environmental settings on the shelf, which are controlled by both geography and climate. Although the majority of the fossils are endemic to the shelf, the communities inhabiting the outermost parts of the shelf probably included some "cosmopolitan" forms from the open ocean, representing species which would have had access to other continental shelves. Such wide-ranging species are thus very important for showing the time relationships between outer-shelf communities of different continents. Among these "oceanic travellers" are groups known as the agnostid, eodiscid and oryctocephalid trilobites, some of which are present in the Cambrian succession of the Cape St. Mary's Peninsula area. These allow important inter-realm correlations to be made with other parts of the world.

One of the most important correlations possible may settle a long-standing problem concerning the time relationships between the different assemblages characterizing Avalonia and Laurentia. Most notable among these problems was the relationship between groups of trilobites known as olenellids and paradoxidids that was a basis for originally differentiating the Lower and Middle Cambrian. The *Cephalopyge* Zone in the upper part of the Brigus Formation (Branch Cove Member) largely comprises a group of trilobites called "eodiscids" that were first described from outer shelf and continental slope deposits of Laurentia in the Taconic allochthons of New York and Quebec, which lie within the Humber Zone of the Appalachian Orogenic Belt. Their presence in the rocks at Branch indicate a previously unrecognised temporal overlap between the olenellids (found mostly in Laurentian terranes) and the paradoxidids (found mostly in Avalonian terranes). This issue now has to be considered by the Cambrian Subcommission in their deliberations on global subdivisions of the system, as inferences regarding the age of sedimentary sequences based on these faunal contrasts require revision.

In addition to the eodiscids, the top of the Branch Cove Member includes the oryctocephalid trilobite called *Ovatoryctocare granulata,* which is known elsewhere in continental shelf sedimentary rocks of Siberia, China and Greenland. This indicates another potentially important correlation of global significance.

DAY 1 (Late Afternoon): PRECAMBRIAN AND CAMBRIAN SEDIMENTARY ROCKS NORTH OF BRANCH, ST. MARY'S BAY

Field trip stop locations are indicated in Figure 7.

St. John's to Stop 1.1

The route from St. John's to Stop 1.1 follows the Trans-Canada Highway (TCH) to the Salmonier Line junction. Follow Route 90 (Salmonier Line) south to Salmonier, and then turn right on Route 91 through Colinet, and then left on Route 92 towards Branch. The Cape St. Mary's Ecological Reserve is signposted in this direction. Continue on Route 92 to the Red Head River bridge, located slightly more than 39 km from the junction with Route 91. En route, note the prominent flat-topped "mesa" located east of the road south of North Harbour. This is Cape Dog, where a volcanic unit in the Cambrian Chamberlains Brook Formation forms a resistant hilltop. Unfortunately, Cape Dog is not easily accessible without a boat.

Stop 1.1
Red Head Cove: Random, Smith Point and Brigus Formations (Adeytown Group)

This section is located around the mouth of the Red Head River. Cross the bridge on Route 92, and turn left immediately on to an old gravel road that provides parking space. This road is suitable only for high-clearance vehicles, so it is wisest to park close to the highway, and then walk down the road for a few hundred metres to the gravel beach. There are several outcrops of interest in this area, as follows. *Access to the northern part of the section requires crossing the Red Head River on the beach; depending on water levels, this could result in wet feet. Rubber boots or an old pair of sneakers are strongly recommended. The section also requires some clambering over sharp and angular outcrop surfaces, which demands some caution. Be careful of slippery bedding planes near the water !*

At the southwest end of the beach, grey to white quartz-arenites and sandstones of the Random Formation (Adeytown Group) dip steeply to the east and are folded. The outcrop also includes some conglomerates containing red and black rhyolite clasts, which represent a basal facies of the formation. This outcrop is very close to outcrops of sandstone and arkose representing parts of the Heart's Content Formation of the Musgravetown Group, which lie beneath the unconformity in this area, together with a thin remnant of the Crown Hill Formation.

To the northeast, across the mouth of the Red Head River, there is another outcrop of the Random Formation, which is a grey-green quartz-arenite. This dips to the west, and sits structurally above red and pink limestones of the Smith Point Formation, which here contain prominent algal structures. The older-over-younger relationship here indicates some local east-directed thrusting. Continuing to the northeast, the Random Formation is exposed again within the core of a small anticline that has been disrupted by a high-angle fault, and the depositional contact between the Random and Smith Point formations is well displayed. Cross-bedding is visible in the quartzites. Note that the Bonavista Formation (Figure 4) is missing in this area. The section to the north consists of massive red mudstones of the Brigus

Formation (Redland Cove Member), in which bedding is defined well by numerous nodular limestone beds. The Brigus Formation is here disposed in a synclinal structure, the core of which is cut by two late mafic dykes. However, the more distant part of the section is not easily accessible unless the tide is low.

Stop 1.2
Beckford Head: Manuels River Formation and Beckford Head Formation (Harcourt Group)

From Stop 1.1, continue south on Route 92 to the southern edge of the community of Branch, and park in a gravel pit on the west side of the road, about 300 m before the signpost welcoming visitors to Branch. About 50 m south of here, an ATV trail leads east from the road to the Beckford River. Cross the river (if the water is low, this is possible by hopping from stone to stone) and follow the trail on the other side beyond a patch of spruce trees, and then turn towards the shore, descending just west of Beckford Head. *The river may be difficult to cross with dry feet if the water is high, and may be too deep for rubber boots. An old pair of sneakers may be useful for getting to the other side. Also, be careful of ocean waves, especially close to the point.*

The red mudstones on the bank of the river are part of the Chamberlains Brook Formation, which is the upper formation of the Adeytown Group. The coastal portion of the stop illustrates rocks belonging to the Harcourt Group, which consists of deeper water siliciclastic rock that are very different in appearance to the red and green mudstones and carbonates of the Adeytown Group. The first outcrops along the shore are black shales, locally sulphide-rich, of the Manuels River Formation (Harcourt Group). These contain a thin unit of white-weathering green mafic tuff interpreted as the lateral equivalent of the Hay Cove basalts, which form the high hill immediately south of the community of Branch. Continuing eastward, towards Beckford Head, the shales become very dark in colour, and then abruptly pass into grey siltstones and sandstones of the Beckford Head Formation, possibly of turbiditic origin.

DAY 2 (Morning): CAMBRIAN SEDIMENTARY ROCKS OF THE BRANCH COVE AREA

Field trip stop locations are indicated in Figure 7.

Stop 2.1
Easter Cove Section: Brigus Formation (Adeytown Group)

"Easter Cove" is the portion of Branch Cove that lies east of the mouth of the Branch River. It exposes mostly the Brigus Formation (Redland Cove, Jigging Cove, Branch Cove and Easter Cove members), and the basal part of the Chamberlains Brook Formation (Wester Cove Member). It is best accessed from the beach in the community of Branch. The easiest access point for the beginning of the outcrops is about 900 m north of the bridge over the Branch River, where a narrow eroded gully leads to the shore. *Note that the shoreline section lies below some steep cliffs, which are locally unstable, as evidenced by numerous fallen blocks. Be extremely careful around these cliffs ! The complete section is accessible only at low tide, and during rising tides it is possible to become stranded in locations from which it is difficult or impossible to climb out. Be cautious and watch the tide ! Avoid slippery bedding planes close to the water !*

This continuous shoreline section exposes virtually all of the Brigus Formation on the east limb of an anticline. It commences with the Redland Cove member which, as its name suggests, consists of bright red mudstones with green and purple interbeds, and numerous nodular limestones. These rocks were seen also at Red Head Cove (Stop 1.1). The section passes upward into the rather similar Jigging Member and eventually into the Branch Cove Member, in which green mudstone layers contain carbonate debris and fossil material.

Stop 2.2
Wester Cove: Chamberlains Brook Formation (Adeytown Group)

"Wester Cove" is the portion of Branch Cove that lies south of the mouth of the Branch River. The rocks here represent a continuation of the section at Easter Cove, and are dipping gently to the southwest, as they are on the opposite side of the anticline. The section is dominated by the Chamberlains Brook Formation (Wester Cove, Waterfall Brook and Big Gully members). At the stop sign south of the bridge, turn left past the community centre, and park in a large open area overlooking the breakwater and the beach. Walk southward across the beach towards the waterfalls visible about 1 km away. *Note that the precautions noted above for the Easter Cove section apply also to this stop !*

This continuous shoreline section exposes fossiliferous beds belonging mostly to the lower part of the Chamberlains Brook Formation. There are also several late mafic dykes exposed along the section.

The first part represents the Wester Cove Member, consisting initially of blocky, massive olive green mudstone; this unit is fossiliferous, although it takes a practiced eye to see the fossils. This gives way in its upper part to mixed red-and-green mudstones that show the same visually

spectacular colour variation seen at Stop 2.1. The Wester Cove Member gives way to the bright red mudstones of the Waterfall Cove Member, with distinctive green and purple mudstone interbeds, and unfossiliferous limestone nodules.

A prominent wall-like point is formed by the thickest of several late diabase dykes that cut through the red mudstones, with an ESE-WNW trend. Chilled margins and apophyses are visible here, and the thickest dyke is riddled with carbonate veins, which show interesting folded patterns indicating the movement sense on some small N-S trending faults that cut the outcrop.

Beyond the dykes, the red mudstones continue for some distance on the wave-washed platform, but the cliffs above are actually the blocky green-brown mudstones of the Big Gully Member, which come to shore beyond the next waterfall. The cliffs to the south comprise the higher parts of the formation, namely the Head Cove and Cape Shore members, which will not be visited.

The return to the parking area can be along the same route as the outbound traverse, but there is an alternate route which may be quicker. At the mafic dykes, a vegetated gully (full of wild mint) just north of the waterfall can be ascended with care, to a clifftop path that joins the paved road in Branch.

DAY 2 (Afternoon): UPPERMOST CAMBRIAN SEDIMENTARY ROCKS AND SILURIAN MAFIC INTRUSIONS OF THE POINT LANCE AREA

Field trip stop locations are indicated in Figure 7.

Stop 2.3
Point Lance River: Gull Cove Formation (Harcourt Group)

From Branch, drive about 6 km west on Route 100, and then turn south along the road to Point Lance. This narrow road twists through the endless barrens and then descends to the valley behind Lance Cove, one of the finest sandy beaches in Newfoundland. About 9 km from the junction, the road crosses the Point Lance River. Turn left into a small gravel pit just north of the bridge, and park. Cross the road, and then cross the flat ground to the river.

This large outcrop shows the well-bedded shales and thin siltstones and sandstones of the Gull Cove Formation, which is the uppermost unit in the Harcourt Group. If the water in the river is low, it can be examined directly; if not, there is a smaller roadside outcrop just south of the bridge.

Stop 2.4
Bull Island Point: Silurian Mafic Intrusive Rocks

Drive through the village of Point Lance, which is one of the most isolated communities in the region, and certainly one of the foggiest. The road eventually meets the superb sandy beach. If the weather is good and there is no wind (we can but hope) the beach serves as an ideal

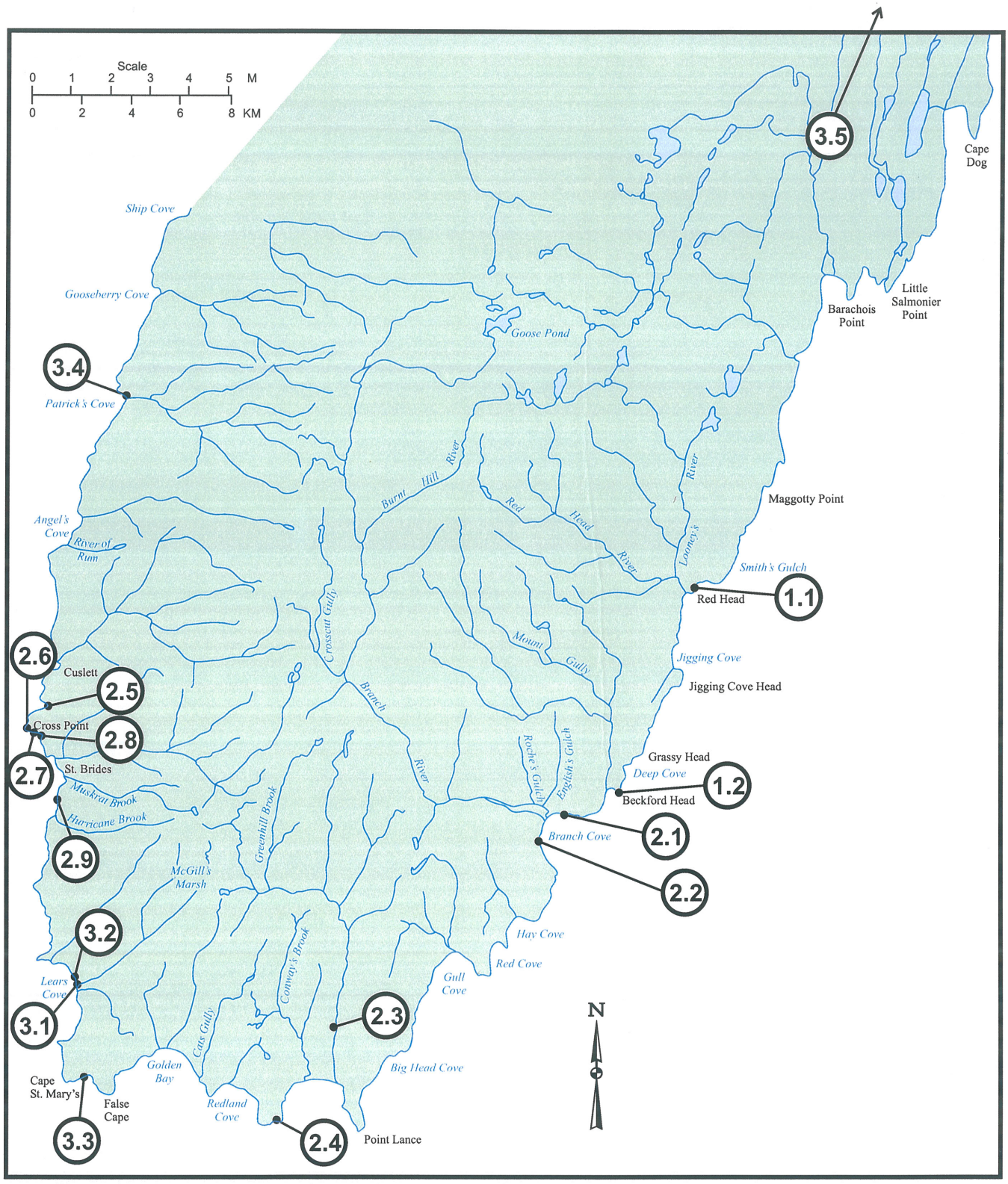

Figure 7. The locations of field trip stops in the Cape St. Mary's Peninsula area. For geological context of individual stops, see Figure 2. Modified after Fletcher (2006).

place to eat lunch. At the end of the pavement, continue (with care) on a steep and narrow dirt road that in places has a cliff-like drop to the water. The road has some deep water-filled potholes, and is locally rocky; it is suitable only for high-clearance vehicles. It leads to an abandoned wharf on the east side of Bull Island Point. Park at the end of the road and walk down to the remains of the wharf.

This is a spectacular spot, but it can be very dangerous in stormy conditions. The near-total destruction of the concrete wharf is a testament to the violence of breaking waves. Be very attentive to the sea state, and do not venture on to the rocks in rough conditions. In any conditions, stay well away from the water !

This locality exposes one of the thickest of several Silurian mafic intrusions within the Cambrian Gull Cove Formation. The gabbroic rocks consist mostly of plagioclase and calcic augite, but cumulus olivine is present locally (Fletcher, 1972; Greenough and Hodych, 2001). This location does not expose contacts with the country rocks, but it does show cumulate layering and later granophyric segregations. Some of the best cumulate layering is seen in large blocks that have been used to prevent access to the ruined wharf. Granophyric segregations (containing some quartz, and also baddeleyite) are present in several areas, most prominently about 75 m west of the wharf, where they form a gently east-dipping sheet preserved on an outcrop surface. Weak layering is also preserved in some of these outcrops. Sandstones and shales of the Gull Cove Formation (Harcourt Group) are visible in the cove immediately east of the wharf.

As discussed in the first part of the guide, these mafic intrusions provide important paleomagnetic data for western Avalonia during the Silurian (Hodych and Buchan, 1996).

DAY 2 (Late Afternoon): CAMBRIAN SEDIMENTARY ROCKS OF THE ST. BRIDE'S AREA

Field trip stop locations are indicated in Figure 7.

This section of the field trip is in three parts. If time and weather conditions permit, we will complete a loop walk to the scenic locality of Perch Cove, then to Cross Point, and back to St. Bride's through Deadman's Cove (about 5 km in total). Circumstances may force us to omit the Perch Cove segment of this walk, in which case Cross Point and Deadman's Cove will be completed as a shorter out-and-back walk of about 3 km. The rock formations described at Perch Cove will then be visited during a shorter stop at the southern end of Distress Cove, behind the St. Bride's fish plant.

Note that walking to Perch Cove requires crossing open heathland that is in places marshy, and waterproof footwear is strongly recommended. The descent to Perch Cove from the cliff tops is moderately steep, but safe; the return hike from the cove involves a moderately strenuous ascent. Descending to and ascending from Deadman's Cove is easier, and the return trail is generally dry.

Stop 2.5
Perch Cove: Smith Point Formation, Mafic Dykes and Late Faults

This beautiful sheltered, steep-walled cove was used for many years as a harbour for fishing vessels prior to the development of the modern man-made harbour at St. Bride's. The access to the cove is via an ATV trail that leads west from Route 100 about 300 metres north of the "Welcome to St. Bride's" sign on the northern edge of the town. There is a gravel pit just south of the sign that provides a suitable parking area. The trail leads through tuckamore and across a few wet areas for about 700 m, before emerging on a larger bog. Turn left across the bog, and then walk southwest along for another 250 m or so to the coast, using some pink outcrops as a directional marker. At the outcrops (Smith Point Formation, see below), admire the views of Cuslett Point to the north, and then turn south to Perch Cove. There is only one route down into the cove, which leads to the point on its north side. If time is limited, many of the features noted below can just as easily be seen from the top of the slope.

The point in Perch Cove consists of nodular pink and red limestones of the Smith Point Formation (Adeytown Group) also seen on Day 1 at Red Head Cove. The cliffs on the north side of the cove show the rather intricate primary depositional structures of the limestone formation, and also show its contact with underlying red, brown and purple mudstones of the underlying *Bonavista Formation*. The sequence here differs from that seen at Red Head Cove on Day 1, where the same limestones sit directly upon quartzites and sandstones of the Random Formation. These stratigraphic relationships indicate that the base of the Smith Point Formation is a important disconformity within the Adeytown Group.

The inner part of Perch Cove consists of the overlying rocks of the Brigus Formation, seen earlier today at Branch Cove. Several high-angle faults coalesce here and emerge through Perch Cove, and the cliffs are consequently unstable and friable. There are at least ten diabase dykes visible in the cliff face, and some of these are visibly offset by minor faults. A diabase dyke is also visible at the north side of the Smith Point Formation outcrop. The south side of Perch Cove lies on the opposite side of the faults, and is upthrown relative to the north side. The cliffs consist entirely of arkoses and conglomerates of the Precambrian (Ediacaran) Crown Hill Formation (Musgravetown Group) which will be visited at the next stop.

Stop 2.6
Cross Point: Crown Hill Formation and sub-Cambrian Unconformity

From Stop 2.5, climb back up the slope on the south side of Perch Cove and turn east, following the top of the cliffs. An old trail is faintly visible here, and eventually turns inland through the tuckamore. Turn right onto another old trail that leads to an area of marshes, and follow it south through the drier areas. This indistinct trail eventually becomes a well-defined track that follows the cliffs around the cove. *The cliffs are unstable and dangerous; under no circumstances should the edge be approached too closely !* Follow the trail through the meadows south of Perch Cove. Beyond a stone cairn, fork left on a fainter trail that leads directly

to Cross Point, which consists of some large outcrops in the distance. *The point is vulnerable to breaking waves in rough weather, and it is wise to stay well away from the water.*

The large exposures at this locality consist of massive dark red to purple pebble conglomerates and interbedded arkoses of the Crown Hill Formation of the Musgravetown Group. This is the type location of the Cross Point Member, which is the youngest Precambrian formation on the Cape St. Mary's Peninsula. The rocks here are closely similar to the well-known conglomerates of Signal Hill in St. John's, to which they are in fact loosely time-equivalent.

About 50 metres west of the main outcrop at Cross Point is a smaller outcrop in which the purple-red conglomerates are overlain by greyish beds. This rather subtle feature is actually the sub-Cambrian unconformity, although the angular discordance across it here is only about 10 degrees. The grey unit is the oxidized top of the Crown Hill Formation, i.e., below the basal cobble congolmerate of the Random Formation (Adeytown Group).

At this stop, the Cambrian rocks sit upon the youngest Precambrian strata. This contrasts with Stop 1.1 at Red Head Cove, where the rocks below the same unconformity belong to the much older Heart's Content Formation. Thus, although the angular discordance between the Precambrian and Cambrian sequences is not great, it is clear that the base of the Random Formation cuts down into the stratigraphy of the Musgravetown Group.

Stop 2.7
Deadman's Cove: Random Formation, Structural Complexities and Late Dykes

If the tide is low, and time is abundant, it is possible to walk along the continuous shoreline section from Stop 2.6 to Stop 2.7. However, under most conditions it is quicker to retrace the trail from Cross Point for about 400 metres, and then walk south to the shore along a prominent grassy gully. From here, the shoreline section from Stop 2.7 to Stop 2.8 is easily traversed under all but the highest tide conditions. *This coastline is exposed, and is vulnerable to large waves under stormy conditions. The flat outcrop surfaces offer no protection from breaking waves. Be attentive to sea conditions at all times, and stay well away from the water !*

This entire section consists of siltstones, sandstones and quartz-arenites of the Random Formation, which dip gently to the southeast. The siltstones contain fine-scale, delicate laminations, whereas sandstones and quartzites display locally spectacular cross-bedding. Numerous primary sedimentary structures are visible throughout the section, both in cross-section and on the large subhorizontal bedding planes. At the eastern end of the section, close to its contact with the reddish mudstones of the overlying Bonavista Formation, spectacular folds are developed in well-bedded quartzites. These range from monoclinal to locally westward overturned. Tight folding is best developed in the more thinly-bedded units.

Late diabase dykes occur through the section, and clearly cut through the fold structures at high angles. The major dykes trend at about 140 degrees, whereas smaller dykes and dyke apophyses trend at about 110 degrees.

Stop 2.8
Deadman's Cove: Barite Veins

Continue beyond the folded zone to a set of prominent pink veins that mark the end of the accessible coastal section at Deadman's Cove. *The cliffs here are steep and are locally overhanging. Stay well away from the cliffs and, if collecting samples of barite, remove loose blocks to a safe distance before hammering them !*

The veins consist of massive barite, and cut through the contact between the Random Formation and the overlying Bonavista Formation. In detail, there are three major veins and numerous smaller veins. Collectively, the veins define a ladder-like pattern in which the major veins dip southeast and the smaller veins (the rungs) dip northwest. The veins are associated with a faulted zone that has a southeast dip and a normal motion, based on displacement of the Random - Bonavista formational contact.

Stop 2.9
South Side of Distress Cove: Cross Point and Bonavista Formations

This stop is an alternate to Stop 2.5 at Perch Cove. It is located at the end of the road in St. Bride's, behind the fish plant and south of the harbour. Park behind the fish plant and walk down an old road for about 50 metres to the shoreline.

The outcrops by the water are dark red mudstones of the Bonavista Formation (Cuslett Member) which contain prominent nodular limestone beds. These are cut by a late diabase dyke. It is impossible to continue more than a few metres along the coastal section due to a deep, slot-like gap filled with surging water. Climb up the rocky slope here to the foghorn enclosed by the wire fence. The outcrops adjacent to this structure are the red and pink bedded nodular limestones of the Smith Point Formation, seen also at Red Head Cove on Day 1, where they sit directly upon Random Formation quartzites, and the Bonavista Formation is absent.

DAY 3 (Morning): PRECAMBRIAN SEDIMENTARY ROCKS AND SEABIRD COLONIES OF THE CAPE ST. MARY'S AREA.

Field trip stop locations are indicated in Figure 7.

These stops illustrate some of the Late Precambrian (Ediacaran) formations of the Musgravetown Group, in the area around Cape St. Mary's itself. Stops 3.1 and 3.2 are situated at Lears Cove, and are accessed by walking down part of the old trail that links St. Bride's and Cape St. Mary's. Stop 3.3 is at the Bird Sanctuary itself.

Stop 3.1
Lears Cove: Arkose and Sandstone of the Maturin Ponds Formation

From Route 100, turn south on the access road to the Cape St. Mary's Ecological Reserve. This is a narrow road and must be driven with caution. At about 6.6 km from Route 100, the road crosses the brook flowing to Lears Cove. Continue for another 3 km, and then turn right into a small gravelly turnout with a narrow access road. This is the only place to park, as the road is much too narrow. The old trail to Lears Cove leads north initially, and then turns towards the coast, running through tuckamore and wetlands for about 1 km, eventually descending to the coast. *The trail is in variable condition, and the first 300 metres or so may be very wet and soggy; waterproof footwear is strongly recommended. This is a relatively exposed section of coastline that may be subject to large swells and dangerous waves. Do not attempt to examine it under stormy conditions and be attentive to sea conditions at all times !*

Descending to Lears Cove, the trail runs alongside a small brook which exposes a thick section consisting of a thinly-bedded reddish lower unit and a more massive pale grey upper unit. Diabase dykes are also visible in the brookside exposures. Cross this brook near the beach, and walk northward to a second larger brook, which should be easy to cross by rock-hopping. The gently north-dipping beds on the point immediately north of the brook are the area of most interest. These represent the False Cape Member of the Maturin Ponds Formation (Musgravetown Group). The exposed section displays superb sedimentary structures, including flaser bedding, ripple-drift structures, scours, cross-bedding, small-scale channelling and many other features indicative of a high-flow fluvial regime. In addition to the outcrops, large loose blocks display superb sedimentary structures. A diabase dyke occurs at the landward end of the point.

Stop 3.2
Young's Point: Conglomerate Marker Unit

From Stop 3.1, follow the old trail up the hill north of Lears Cove, and then turn left along a faint trail through the coastal meadows, towards a large pile of rocks about 200 metres to the north.

The large boulders are a disrupted outcrop of the Youngs Point Member of the Maturin Ponds Formation. This is a pebble conglomerate unit with a varied clast population including

quartz pebbles, felsic volcanic rocks and other sedimentary rocks. It is an important marker horizon in this part of the Musgravetown Group. The location has spectacular views of the cliffs and gravel beaches on the north side of Lears Cove, and is surrounded by wildflowers. It is a wonderful place to sit and listen to the undertow a-hissing.

Stop 3.2
Cape St. Mary's Ecological Reserve

From Lears Cove, walk back along the old trail to the Cape St. Mary's road. Continue south on the access road for about 3 km to the Interpretation Centre and the lighthouse. The interpretation centre contains fascinating exhibits on the wildlife and natural history of the area. In fine weather, the area around the lighthouse provides fantastic views. From the interpretation centre, a well-defined trail leads to the bird sanctuary through green meadows full of grazing sheep. This provides excellent views of bird rock, which is the largest of the colonies, and terminates at a steep cliff alongside the sea stacks, from which the nesting gannets and other species may be observed at close quarters.

The spectacular cliffs around the lighthouse and the bird colony are also extremely dangerous. Stay on marked trails only and do not venture beyond safety barriers. Stay well back from the cliff edges, especially on the narrow cliff-bounded promontory alongside Bird Rock. A fall from these heights would most definitely be fatal. Be particularly careful to stay on marked trails if conditions are foggy. This is a very bad place in which to become disoriented !

The area around the Ecological Reserve is underlain by late Precambrian arkosic sandstones and siltstones of the Big Head Formation of the Musgravetown Group. The higher area to the east of the Bird Sanctuary is the basal section of the overlying Maturin Ponds Formation, visited at Lear's Cove. The bedding is virtually flat-lying throughout this area, because it is in the core of the regional anticline (Figure 2). The attitude of bedding provides numerous ledges for nesting sites.

Bird Rock is the southernmost gannet colony in the world. In addition to the gannets, common murres and black-legged kittiwakes are also commonly seen to nest in this area. Rarer species include thick-billed murres, razorbills and black guillemots (Montevecchi and Tuck, 1987). The flat bedding surfaces are especially favourable for birds such as murres, because they do not build nests for their eggs. Further information about the Bird Sanctuary and its feathered inhabitants will be provided during the field trip by Mr. Tony Power of the Department of Parks and Natural Areas.

DAY 3 (Early Afternoon): MAFIC DYKES OF PATRICK'S COVE

Field trip stop locations are indicated in Figure 7.

Stop 3.4
Patrick's Cove: Crown Hill Formation and Late Mafic Dykes

From the Cape St. Mary's Ecological Reserve, return to Route 100, and drive north through St. Bride's, and continue north to Patrick's Cove, located about 13 km from St. Bride's. Turn left on a side road just north of the bridge across the river, and park close to the lovely sand beach. Walk northward along the beach to the outcrops. *This is a shoreline locality that is subject to large waves at times. Be attentive to sea conditions at all times !*

The outcrops form part of the Crown Hill Formation of the Musgravetown Group, and consist of red arkoses and conglomerates containing red mudstone clasts, interbedded with laminated red sandstones and siltsones. At this location, they are part of the Hurricane Brook Member, which sits beneath the conglomeratic rocks of the Cross Point Member, visited at Stop 2.6. These are cut by numerous mafic dykes, some of which preserve good chilled margins. Cross-cutting relationships can be observed between different dykes, and displacements of older dykes indicate that fault movements occurred prior to or contemporaneously with emplacement of younger dykes. One dyke contains spectacular large plagioclase megacrysts and crystal aggregates. These must have developed in a deeper magma chamber from which the magmas ascended or through which they passed; it is interesting to think that there might be Devonian (or Triassic ?) anorthosites in the deep crust of the Avalon Peninsula.

DAY 3 (Late Afternoon): HOLOCENE GORGES NEAR COLINET

Stop 3.5
Cataracts Provincial Park

This is an optional stop providing a break on the way back to St. John's and will only be visited if time permits.

From the Cape St. Mary's area and/or Patrick's Cove, drive northward on Route 100 towards Placentia. This is justly regarded as one of the most scenic roads in eastern Newfoundland. Before entering Placentia, turn right on Route 91 towards Colinet. This is a generally well-maintained gravel road; however, watch out for sections with corrugations or bad potholes. Cataracts Provincial Park is signposted a few kilometres west of Colinet. A bridge constructed in 1926 spans the gorge, on what was at one time the main road between St. John's and Placentia. These deeply-incised river gorges on a tributary of the North Harbour River are easily accessible via stairs and boardwalks. The rocks here are shales and siltstones of the Musgravetown Group. *Participants should stay on the boardwalks at all times, as falling in the river would be both stupid and dangerous !*

From Cataracts Provincial Park, continue east on Route 91 to Colinet and Salmonier, and from there north to the Trans-Canada Highway and St. John's.

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