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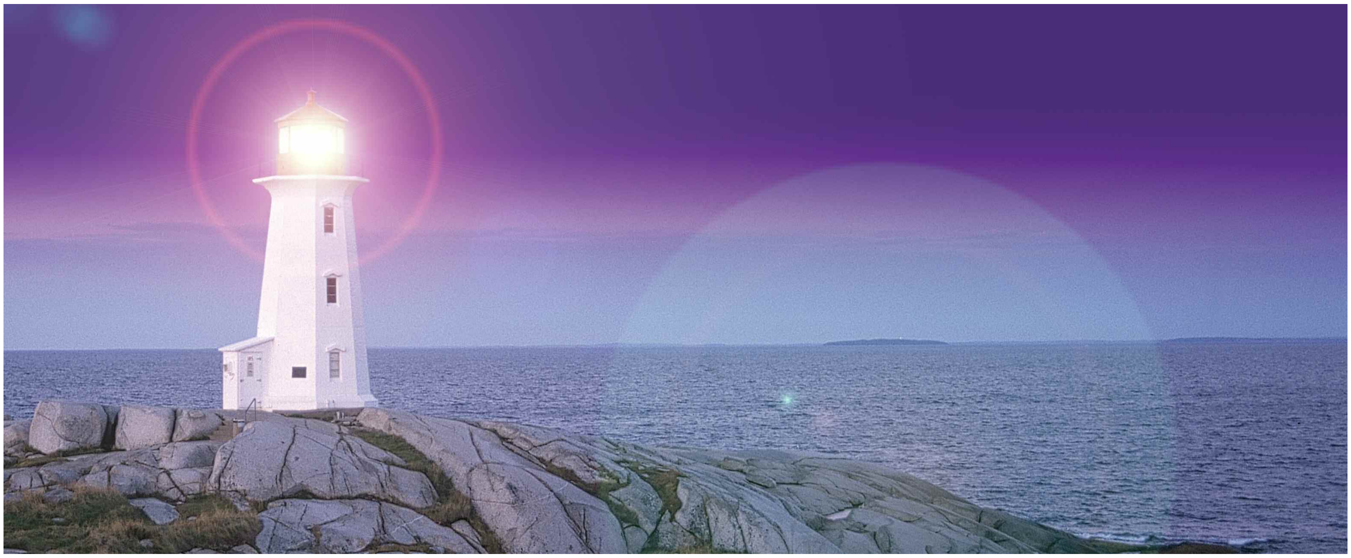

FIELD TRIP B9

Gold metallogeny in the Newfoundland Appalachians

Andrew Kerr, Richard J. Wardle, Sean J. O'Brien,
David W. Evans, and Gerald C. Squires

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Gold Metallogeny in the Newfoundland Appalachians

Andrew Kerr (compiler), Richard J. Wardle, Sean J. O'Brien, David W. Evans, and Gerald C. Squires

Newfoundland Department of Natural Resources, P.O. Box 8700
St. John's, Newfoundland, Canada A1B 4J6

Department of Earth Sciences
Dalhousie University
Halifax, Nova Scotia, Canada B3H 3J5

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NORTH ATLANTIC MINERALS SYMPOSIUM - FIELD TRIP

GOLD METALLOGENY IN THE NEWFOUNDLAND APPALACHIANS

Native gold from the Dorset Vein, Baie Verte area. Photo courtesy of Paul Crocker and Grayd Resource Corporation.

A. Kerr (compiler), R. Wardle, S.J. O'Brien, D.W. Evans and G.C. Squires

Geological Survey of Newfoundland and Labrador
Department of Natural Resources
P.O. Box 8700, St. John's, NL A1B 4J6

Field trip organized by the Newfoundland Section of the Geological Association of Canada for the North Atlantic Minerals Symposium

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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.

Specific Hazards

Most of the stops are reached by paved or gravel road from which they are easily accessible by foot, by either well-defined trails or short scrambles. Care should always be taken when visiting any site, especially those adjacent to the coast or in roadcuts, where the hazard of falling debris from the slopes above is a real one. In such situations, we advise participants not to put themselves in jeopardy by attempting to ascend such slopes, and to maintain a safe distance. In coastal settings, participants may be vulnerable to freak waves, and should maintain a safe distance from the high water line. Weather is unpredictable 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. Do not walk straight down steep slopes if others are also on the slope below. Instead, proceed down slopes at an angle. Several stops are adjacent to highways, and participants must take great care in crossing them. Groups crossing together are particularly vulnerable, and each individual must take responsibility for their own safety. Some stops are at the top of steep cliffs or slopes. Participants should stay well back from the cliff edge at all times. Overhangs are common on unconsolidated cliffs, and often are not visible from above.

We strongly recommend sturdy footwear that provides adequate protection and ankle support. Two stops are in the valleys of brooks, and other stops may be in areas of wet ground. Participants may wish to bring spare footwear for use at stops in brooks, where there is a strong possibility of getting wet feet.

Safety Information in the Guidebook

Part 3 of this guidebook contains 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.

ACKNOWLEDGMENTS

This field trip guide was initially envisaged as a collage of previous publications, but it ended up in a rather different format. The authors acknowledge the valuable assistance of staff from the Geological Survey of Newfoundland and Labrador in its preparation. Chris Pereira is thanked for providing copy-editing assistance throughout, and Joanne Rooney is thanked for grappling with the text and greatly improving format and appearance throughout. The cartography section (Dave Leonard, Tony Paltanavage and Terry Sears) are thanked for their work on diagrams and figures. Cees Van Staal of the Geological Survey of Canada is thanked for providing us with a copy of a review paper from which we have summarized recent plate-tectonic models for the Appalachians in Newfoundland. The stop descriptions in Part 3 of this guide are drawn from previous public-domain summaries provided for other field excursions and reports, and we thank the numerous major and junior mineral exploration companies for use of this information, and for permission to visit their properties.

The Geological Survey of Newfoundland and Labrador, through the North Atlantic Minerals Symposium (a joint effort with the Geological Survey of Ireland) provided valuable in-kind assistance for this field trip, and the production of this guidebook.

PREFACE

This seven day field trip is intended to fulfill two objectives. The first objective is to provide an overview of gold mineralization in the context of the temporal and spatial framework of the Appalachian Orogenic Belt in Newfoundland. The second objective is to link aspects of gold metallogeny to the geological and tectonic framework of Newfoundland, and introduce participants to an area that many consider to be the *type area* for Appalachian tectonic evolution. As with any field trip, we face the challenge of accommodating varied levels of expertise and areas of interest amongst participants. Thus, our approach is to mix stops that emphasize mineralization with stops that highlight key geological relationships.

The field trip is organized from east to west, starting in St. John's and ending in Deer Lake. Day 1 will focus upon late Precambrian epithermal-style gold mineralization of the eastern Avalon Peninsula, mostly within 40 km of St. John's. Day 2 will commence with a brief examination of late Precambrian gold mineralization west of the Avalon Peninsula, and conclude with examination of Paleozoic gold mineralization of both orogenic (mesothermal) and epithermal type in the area east of Gander. Days 3 and 4 will examine gold mineralization of both orogenic (mesothermal) and epithermal types in central Newfoundland, mostly in the area between Grand Falls and Gander Bay, which is an important focus for recent mineral exploration. Day 5 will commence with examination of auriferous veins hosted by turbidite sequences west of Grand Falls, and will conclude with examination of some gold-rich VMS mineralization in the Green Bay area. Day 6 will be devoted to orogenic (mesothermal) gold mineralization of the Baie Verte Peninsula in northwestern Newfoundland. Day 7 will examine unusual gold mineralization in Cambro-Ordovician platformal rocks of western Newfoundland, and orogenic (mesothermal) gold mineralization in the adjacent Silurian cover sequences. The field trip will end in Deer Lake on the afternoon of Day 7.

This field trip guide is not intended to be an exhaustive and complete treatment of gold mineralization in Newfoundland, nor is it intended to cover all aspects of the Paleozoic tectonic evolution of this key area in the northern Appalachians. It is instead intended to summarize both topics, to provide an outline of regional geology in the areas visited, and to provide basic descriptive information for individual field stops. We have attempted to provide a detailed bibliography that will allow participants with specific interests to obtain more detailed information. It should be noted, however, that for some mineralized localities there is very little public domain geological information, as the company assessment reports mostly remain confidential. We hope to provide supplementary material for some of these areas, from unpublished Geological Survey and corporate sources.

This guide is organized in three sections. Section 1 summarizes the Precambrian to late Paleozoic geology and tectonic evolution of the Appalachians in Newfoundland. Section 2 provides an overview of gold mineralization environments currently recognized across the island. Section 3 contains the stop descriptions for locations to be visited, and provides more detailed summaries of local geology, exploration history and mineral deposit geology. Weather conditions and other logistical constraints (e.g., tides, road conditions, etc.) will determine the exact order of field visits, and whether all the individual stops listed are actually visited. Some of the stops described in Section 3 may not be possible due to the above factors, and also time constraints. We may also make short stops at localities not described in this guide. Participants should expect some changes from the itineraries detailed herein!

SECTION 1: AN OVERVIEW OF THE GEOLOGIC AND TECTONIC EVOLUTION OF THE APPALACHIAN OROGEN IN NEWFOUNDLAND

(A. Kerr)

INTRODUCTION

This chapter of the guidebook provides an overview of the geology of the Appalachian Orogen in Newfoundland and discusses recent plate tectonic models. It is derived from many different sources, including guidebooks from previous field trips. In particular, it draws upon the "Trans-Newfoundland" guidebooks of Cawood *et al.* (1988) and Williams (2001), with updates to cover work conducted since 2001. Other sources include a field trip guide to southwest Newfoundland completed in conjunction with the LITHOPROBE project (Colman-Sadd *et al.*, 1992a), more detailed overviews of central Newfoundland geology and metallogeny (Swinden *et al.*, 2001; Evans (2001a), and a review of Appalachian-cycle plutonism in Newfoundland (Kerr, 1997). Discussions of tectonic models draw upon a recent summary article by Van Staal (2005) and a more detailed review paper (Van Staal, *in press*). These papers and guides all provide extensive reference lists for specific areas and topics.

The Appalachian Orogen, and its continuation in the Caledonides of Europe and Scandinavia, have profoundly influenced ideas concerning the origin of mountain belts for almost 200 years. Newfoundland has earned a reputation as the *type area* for Appalachian tectonic and geological evolution by virtue of its well-exposed coastal sections across the belt and the relative paucity of younger cover rocks. The island also forms a vital link between the Appalachian Orogen of North America and the Caledonides of Britain and Ireland, which were contiguous with Newfoundland prior to the Mesozoic opening of the modern Atlantic Ocean. In the late 1960s and early 1970s, Newfoundland also played a pivotal role in the debate concerning the application of plate tectonics to ancient orogenic belts, and it became a natural field laboratory in which these ideas were tested. The island became particularly well-known for its well-preserved ophiolite suites, and for an extensive tract of early Paleozoic volcanic and sedimentary rocks that formed in the proto-Atlantic, or *Iapetus Ocean* (*see below*). The recognition of the two-sided symmetrical geological pattern of the Newfoundland Appalachians by Williams (1964) was one of the key elements in *"Did the Atlantic close and then reopen?"*, published by J. Tuzo Wilson in 1966. The modern Atlantic is a Mesozoic and younger ocean which separated and dispersed several portions of an originally continuous orogenic belt almost 8000 km long, which stretches from the Mauritanides of west Africa to northern Scandinavia and Spitzbergen (Figure 1.1). Almost forty years hence, fundamental zonal subdivisions first established in Newfoundland provide a descriptive framework throughout the belt, and geological studies in Newfoundland continue to influence plate tectonic models.

GLOBAL TECTONIC FRAMEWORK OF THE APPALACHIAN–CALEDONIAN OROGENIC BELT

The development of the Appalachian–Caledonian Orogenic Belt is generally viewed in terms of two large-scale events, i.e., the breakup of the Neoproterozoic supercontinent *Rodinia*, and the subsequent closure of two oceanic basins, the *Iapetus Ocean* and the *Rheic Ocean*. These events led to the formation of the late Paleozoic supercontinent *Pangaea*. The breakup of Rodinia commenced prior to ~750 Ma ago, and allowed *Laurentia* (i.e., modern North America and Greenland) to drift from a high southerly latitude to an equatorial position, separating it from *Gondwana* (Africa, South America, Antarctica and parts of Europe), which remained at high southern

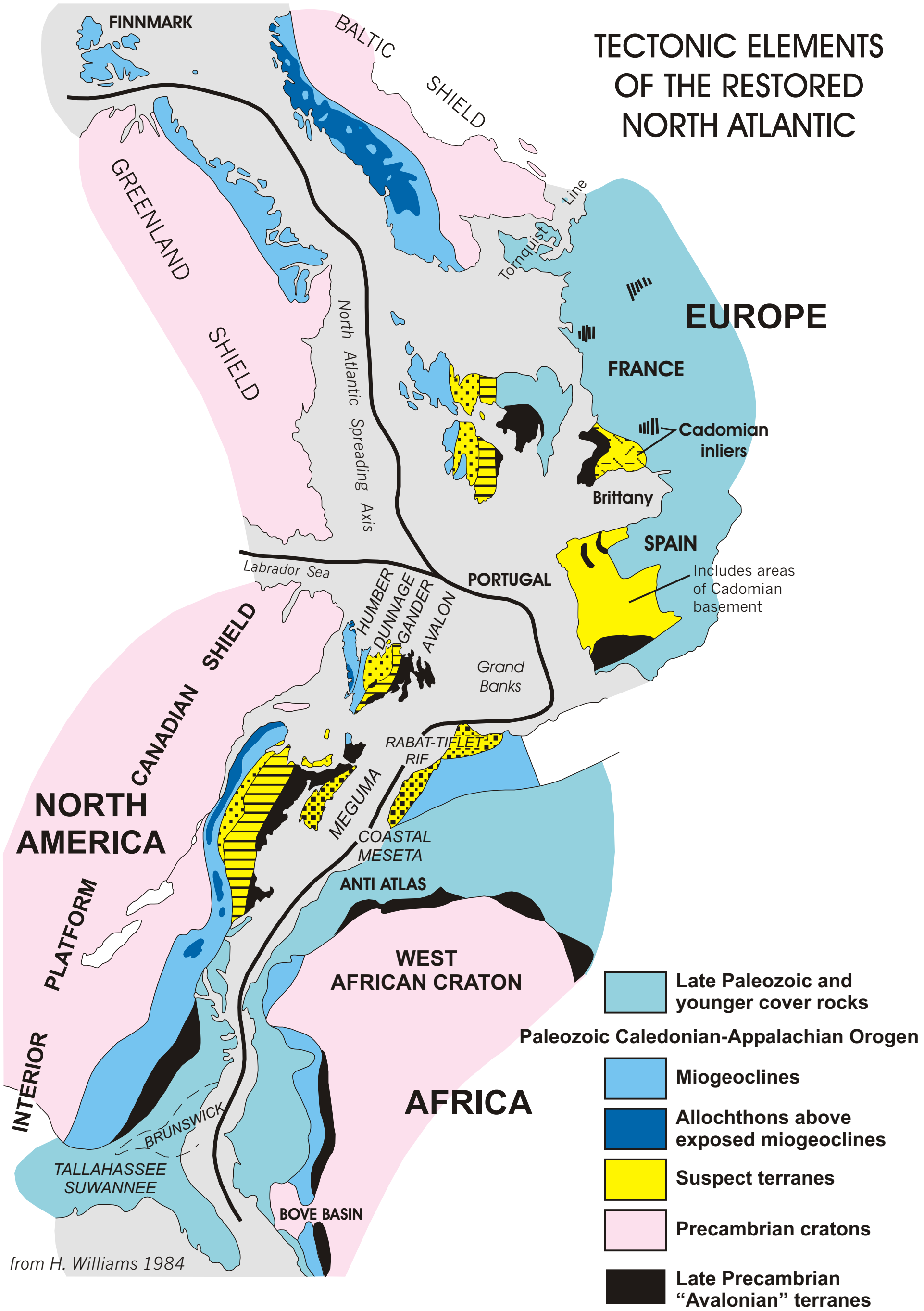


Figure 1.1: *Cratonic regions, miogeoclines and suspect terranes of the restored North Atlantic Region (from Williams, 1984, 1995, with modifications).*

latitudes. During the formation of the Iapetus, some parts of Gondwana became independent microcontinental blocks and separated from the remaining part of the continent. The largest of these formed the region now called *Avalonia*, preserved in eastern North America and Europe (Figure 1.1). The main Iapetus Ocean separated Laurentia from Avalonia and the region known as *Baltica* (i.e., the Baltic and Russian shields), which was also an independent continental block during the early Paleozoic. The *Rheic Ocean* separated Avalonia from the remainder of Gondwana, which remained near the south pole. During the late Precambrian and the Cambrian, the Iapetus Ocean steadily grew in size, achieving a width of several thousand kilometres.

During the Ordovician, the Iapetus Ocean began to shrink. Island arcs developed within it in response to subduction, such that it eventually resembled parts of the modern Pacific Ocean. The northern part of the Appalachian–Caledonian Orogenic Belt was eventually formed by the collision of Laurentia with these island arcs, followed by collision with Baltica and Avalonia. These protracted events terminated in the Silurian or in the Devonian, depending upon geographic location. This accretionary event was then followed by the closure of the Rheic Ocean, which eventually culminated in the collision between conjoined Laurentia–Baltica–Avalonia and the remainder of Gondwana. This terminal collision occurred during the Carboniferous, recording the assembly of the supercontinent *Pangaea*. Carboniferous orogenic events are important in central and southern Europe, where they define the wide Variscan Orogenic Belt, and they are also prevalent in the southern part of the Appalachians (Figure 1.1). The subsequent breakup and dispersal of Pangaea during the Mesozoic separated various parts of the composite Appalachian–Caledonian–Variscan belt, leaving some parts of Avalonia attached to Laurentia along its eastern margin. Conversely, some parts of Laurentia remained on the European side of the Atlantic, in Scotland and Scandinavia. As Tuzo Wilson proposed in 1966, the Atlantic did indeed close and then re-open, but not in exactly the same places.

ZONAL SUBDIVISIONS OF THE APPALACHIAN OROGEN

The evolution of the Appalachian Orogen in Canada began in the late Neoproterozoic and ends in the Mesozoic. Generally speaking, the rocks that comprise the orogen are divisible into four broad age groupings: Latest Precambrian to Ordovician, Siluro-Devonian, Carboniferous, and Mesozoic. These broad age groupings are lithologically distinct in any one region within the belt, and in most cases they are also separated by major unconformities. Newfoundland is dominated by Precambrian to Silurian rocks, overlain locally (or intruded) by younger Paleozoic rocks, but the island is essentially devoid of Mesozoic rocks. The paucity of Carboniferous and younger rocks is a major contributor to the importance of Newfoundland in understanding the tectonic evolution of the Appalachian–Caledonian Orogenic Belt.

Several “zonal” subdivisions of the Canadian Appalachians have been proposed over time, but the most widely used is a simple five-fold division based largely upon Newfoundland and Nova Scotia (e.g., Williams, 1979, 1995). Working outward from the stable cratonic interior of North America, these five zones are termed the *Humber Zone*, *Dunnage Zone*, *Gander Zone*, *Avalon Zone* and *Meguma Zone* (Figure 1.2). The first four are defined in Newfoundland and recognized elsewhere in Nova Scotia, New Brunswick and Québec, but the Meguma Zone is present only in Nova Scotia. Within a given zone, there are distinct packages of rocks, particularly amongst those of pre-Devonian age, because these zones represented radically different environments, separated by large distances. Devonian and Carboniferous rocks tend to be more consistent in their character across the tectonic zones, because they mostly postdate their juxtaposition. The zones also display contrasts in faunal assemblages, structural patterns, metamorphic grades and geophysical signatures. Some of the zones are subdivided, notably the Dunnage Zone, which consists of contrasting western and eastern sections termed the *Notre Dame Subzone* and *Exploits Subzone* (Figure 1.2). The Humber Zone of western Newfoundland is similarly divided into an “external”, little-deformed subzone and an “interior” subzone which is metamorphosed and structurally complex (Figure 1.2). Late Paleozoic (mostly Carboniferous) rocks are terrestrial, lacustrine and shallow marine cover sequences that transgress zonal boundaries, and unconformably overlie deformed older rocks. In Newfoundland, these form geographically restricted “basins” that are spatially

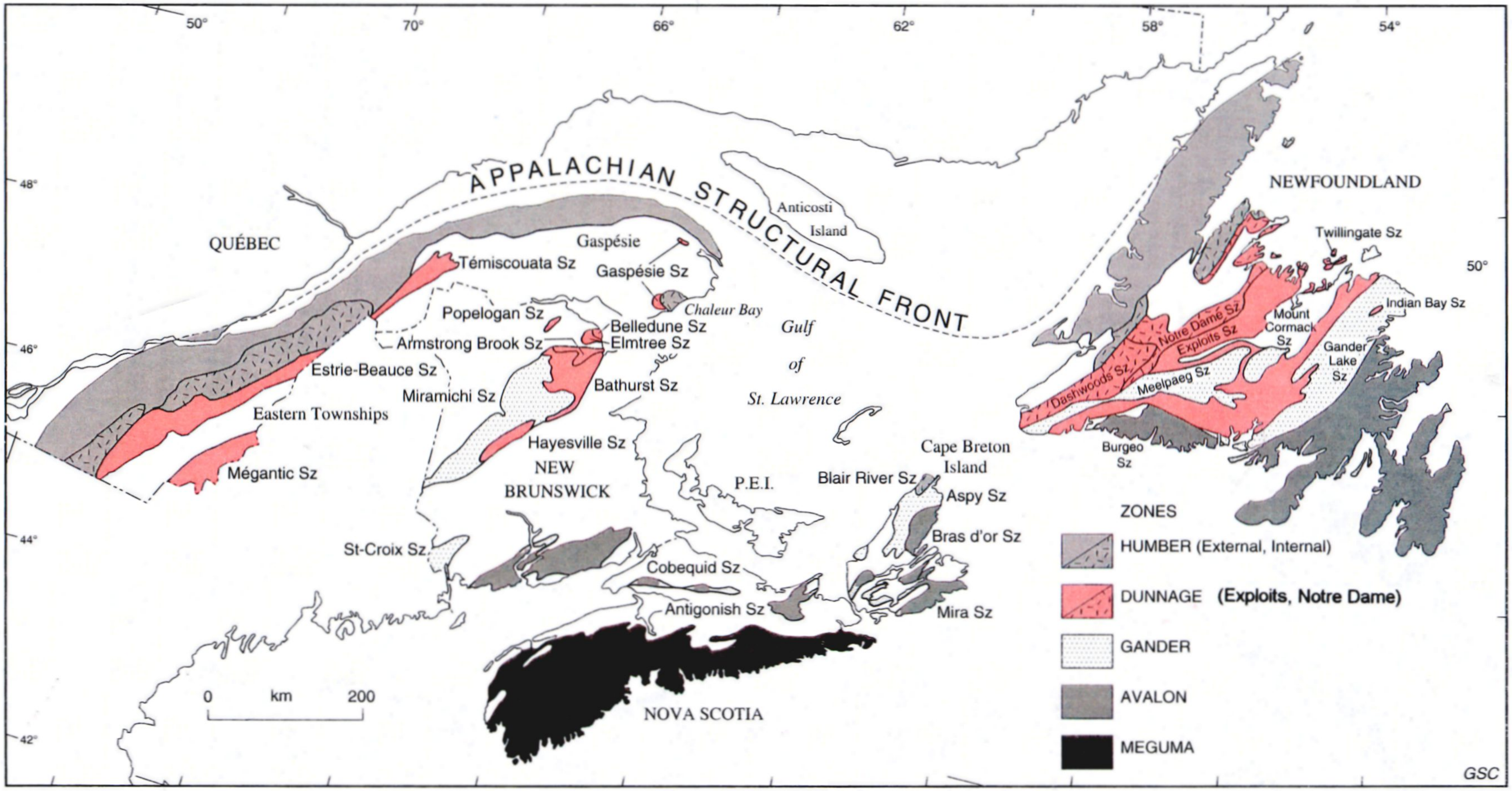


Figure 1.2: *Major zonal subdivisions of the Canadian Appalachians, including Newfoundland (from William, 1995).*

associated with important structural boundaries (Figures 1.2 and 1.3) between and within zones. In Québec and the Atlantic provinces, Carboniferous rocks are more abundant and obscure much of the middle Paleozoic and older history of the orogen (Figure 1.2). The generalized geology of Newfoundland is indicated in Figure 1.3, summarized after the Colman-Sadd *et al.* (1990) geological map of the island.

HUMBER ZONE

The Humber Zone represents the ancient continental margin of ancient North America, termed *Laurentia*. It consists of two main elements: a crystalline basement of Mesoproterozoic to Neoproterozoic age, and a Cambro-Ordovician cover sequence. The Precambrian basement, exposed mostly in the Long Range Inlier of the Great Northern Peninsula, is part of the Grenville Province of the Canadian Shield. The basement rocks are cut by mafic dykes and overlain by associated flood basalts, formed 615 to 600 Ma ago (e.g., Williams *et al.*, 1985; Kamo *et al.*, 1989) that mark rifting events that led to the opening of the Iapetus Ocean during the Cambrian (e.g., Williams and Hiscott, 1987). The earliest cover sequences are dominated by clastic rocks and show strong lateral facies variations, but these are followed by a laterally continuous carbonate platform sequence of Middle Cambrian to Early Ordovician age (e.g., Williams and Stevens, 1974; Lavoie *et al.*, 2003, and references therein). The development of this stable carbonate platform was disrupted at the end of the Early Ordovician when the shelf subsided and foundered in response to the attempted subduction of the Laurentian continental crust beneath island arcs that developed within the Iapetus Ocean (Church and Stevens, 1971; see below for further discussion of models). The former shelf became a deep-water foreland basin that accumulated easterly-derived flysch from a new offshore landmass formed by an imbricate thrust stack including deep-water equivalents of the shelf sequence, capped by a section of oceanic crust and subjacent mantle (Stevens, 1970, Williams and Stevens, 1974). The emplacement of these *Taconic allochthons* across the passive margin marks the Early to Middle Ordovician *Taconic Orogeny*. There are two major allochthons in Newfoundland; the largest is the Humber Arm Allochthon around Corner Brook, which is the location of the well-known Bay of Islands ophiolite suite. Note that the ophiolites, being of oceanic “Iapetan” derivation, are grouped as part of the Dunnage Zone (see below). The eastern part of the Humber Zone includes metamorphic rocks derived from the deep-water equivalents of the platformal sequence, and also structurally complex fold-and-thrust belts that contain a similar stratigraphy to the relatively undisturbed platformal sequence. This internal region of the Humber Zone has been strongly affected by later orogenic events of Silurian age (Salinic Orogeny) and Devonian age (Acadian Orogeny, *sensu stricto*), and was locally invaded by Silurian intrusive rocks, notably around White Bay (Figure 1.3). Volcanic and sedimentary rocks of Silurian age also form a cover sequence in this area, but are essentially absent elsewhere in the Humber Zone of Newfoundland.

DUNNAGE ZONE

The Dunnage Zone is the widest and most complex of the tectonic zones in Newfoundland, and represents the remains of an originally wide oceanic domain, referred to as the Iapetus Ocean. It is now generally believed that the Dunnage Zone preserves the remains of island arcs and marginal basins, rather than representing the main part of Iapetus. The surface geology of the Dunnage Zone is dominated by ophiolite suites and volcano-sedimentary sequences that were formed in a series of Cambrian and Ordovician island arcs and back-arc basins created as the Iapetus Ocean shrank by subduction. Note that the Bay of Islands ophiolites in western Newfoundland are considered to be pieces of the Dunnage Zone transported for hundreds of kilometres across the Humber Zone. The individual volcanic belts within the Dunnage Zone are fragments of many original terranes that could have been separated by large distances and dis-

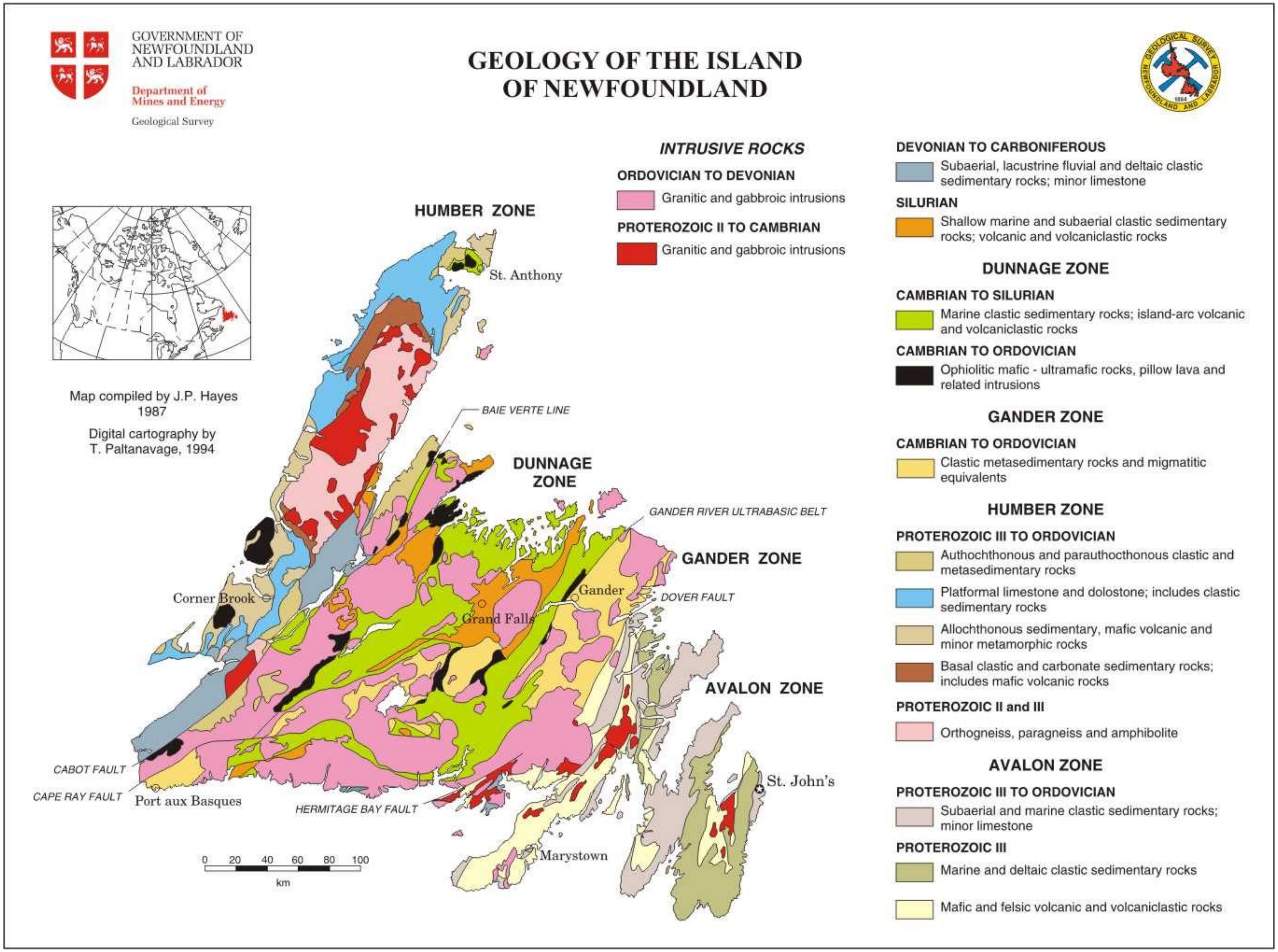


Figure 1.3: *Simplified geology of Newfoundland (after Colman-Sadd* et al.*, 1990).*

placed laterally by later transcurrent faulting. The Dunnage Zone is allochthonous (Karlstrom, 1983) and is floored by continental crust, presumed to be of Laurentian affinity in the west and of uncertain (but non-Laurentian) affinity in the east. Several small inliers of late Precambrian rocks in central Newfoundland (not indicated in Figure 1.3) represent samples of this poorly known eastern basement. Williams *et al.* (1988) proposed a twofold division of the Dunnage Zone into the *Notre Dame* and *Exploits* subzones based on several criteria, including stratigraphy, structure, faunal assemblages, isotopic signatures and regional geophysical patterns. The Notre Dame Subzone is characterized by a well-developed sub-Silurian unconformity, whereas the Exploits Subzone has a more continuous sedimentary record through the Ordovician and into the Silurian. The boundary between the two subzones, a complex zone termed the *Red Indian Line*, is interpreted to be the general surface expression of the boundary between arcs developed on the opposing Laurentian and Gondwanan sides of the Iapetus Ocean (Williams *et al.*, 1988). The western boundary of the Dunnage Zone is defined by the Baie Verte Line, which contains several dismembered ophiolite suites. The eastern boundary of the Dunnage Zone is superficially more complex in its geometry and geology. In the north, the Gander River ultrabasic belt (also known as the GRUB line, or Gander River complex) forms a discrete structural lineament containing dismembered ophiolites, but in the south several structural windows within the Exploits subzone expose metasedimentary rocks that are akin to those of the Gander Zone, located farther east (Figures 1.2 and 1.3). The contact regions between these contrasting packages of rocks are, in part, marked by ultramafic rocks interpreted as dismembered ophiolites. Such relationships imply that the eastern part of the Dunnage Zone was emplaced over the Gander Zone, and the timing of this event appears to be approximately the same as the emplacement of the Taconic Allochthons across the Laurentian margin (Colman-Sadd *et al.*, 1992b). The term *Penobscot Orogeny*, derived from analogous regions in New England, is now commonly used in reference to this event.

Silurian sedimentary and volcanic rocks are locally abundant throughout the Dunnage Zone, with major concentrations in north-central Newfoundland (Figure 1.3). These Silurian volcanic rocks are bimodal but felsic-dominated, and the sedimentary rocks are of shallow marine to terrestrial character. As noted above, there is a prominent sub-Silurian unconformity in the west, but relationships are less well established in the east. Silurian volcanic rocks are also more abundant in the west than in the east. The Dunnage Zone is also invaded by numerous plutonic suites of mafic to felsic composition, most of which also appear to be of Silurian age. Some of the plutonic suites in the west are of alkaline to peralkaline character, whereas the majority in the east are calc-alkaline. Bimodal composite gabbro–granite batholiths are also prominent in the east. Ordovician plutonic suites associated with the Dunnage Zone volcanic belts are present, but are not common. The Dunnage Zone has been affected by Taconic, Salinic and Acadian orogenies, but it is now generally accepted that the most prevalent deformational and plutonic events are of Silurian (i.e., Salinic) age (e.g., Dunning *et al.*, 1990; Cawood *et al.*, 1994).

GANDER ZONE

The Gander Zone lies east of the Dunnage Zone and also occurs within structural windows located in the eastern Dunnage Zone (Exploits Subzone, see above). In earlier years, much of the south coast of Newfoundland was included within the Gander Zone, largely on the basis of metamorphic grade and plutonic assemblages, but the south coast region is now known to contain late Precambrian rocks of comparable age to those of the Avalon Zone (Dunning and O'Brien, 1989). However, the exact relationships between late Precambrian rocks of the Avalon Zone (*sensu stricto*) and those located farther to the west remain a subject of debate (see later discussion).

The dominant package of rocks in the Gander Zone is a wide tract of polydeformed metasedimentary rocks of siliciclastic composition, called the Gander Group. Their age is not well constrained, but likely extends from the Cambrian to the Ordovician. In the northeast Gander Zone, close to its boundary with the Avalon Zone, these are transformed into amphibolite facies gneisses and migmatites that record partial melting and generation of granitoid magmas. High-grade metamorphism is present in many other areas also, but the original sedimentary character of the Gander Group is locally well preserved. The Gander Group metasedimentary rocks have ancient continental sources, and are believed to represent a sedimentary basin developed on the Gondwanan margin of the Iapetus Ocean, but their exact relationship to the adjacent Avalon Zone rocks is debatable, as the two are separated by an important fault zone (Figures 1.2 and 1.3).

Van Staal (2005, *in press*) uses the term *Ganderia*, and suggests that the late Precambrian basement and Paleozoic cover of this region are distinct from those of the Avalon Zone to the east, although both have broadly Gondwanan affinities.

Plutonic rocks occupy much of the Gander Zone, and intrude the metasedimentary rocks. The oldest examples are Ordovician granites of ~470 Ma age that also intrude adjacent Dunnage Zone rocks in central Newfoundland. These granites are of anatectic origin, and constrain the initial juxtaposition of the eastern Dunnage Zone and the Gander Zone during the Penobscot Orogeny (Colman-Sadd *et al.*, 1992b). Younger plutonic rocks fall into three major groupings. Those of Silurian age include peraluminous leucogranites derived in part by anatexis of the Gander Group, and more extensive calcalkaline megacrystic biotite granites that have more mixed sources. U–Pb geochronological data indicate that most of the megacrystic suites are of Silurian age, although earlier isotopic data suggested a Devonian timing. Granitoid rocks of Devonian age *do* occur throughout the Gander Zone, but they are subordinate to the Silurian suites. One large example (the ~380 Ma Ackley Granite of southeastern Newfoundland) transgresses and hides the Gander–Avalon boundary (Figure 1.3). Devonian granites are of calcalkaline character, but are compositionally evolved and potassic compared to their Silurian counterparts. The tectonic history of the Gander Zone is complex, and the region was affected by orogenic events of Ordovician, Silurian and Devonian age. An important period in terms of regional metamorphism and plutonism appears to have been during the Silurian (i.e., the Salinic Orogeny) and this obscures much of the earlier Ordovician history. The ~380 Ma age defined for the Ackley Granite constrains the eventual juxtaposition of the Gander Zone with the Avalon Zone to the east.

AVALON ZONE

The Avalon Zone of eastern Newfoundland (Avalon *sensu stricto* of O'Brien *et al.*, 1996) is largely confined to the Avalon and Burin peninsulas and adjacent areas, but is part of a much larger tract of Late Precambrian rocks that extends through the Maritime Provinces into New England, and the Carolina Slate Belt of the southern USA. (Figure 1.1). This Avalon Composite Terrane was left attached to Laurentia when the modern Atlantic Ocean opened, and severed it from its correlative terranes in the British Isles, western France and parts of North Africa (Figure 1.1). The geological record of the Avalon Zone is mostly 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. The Avalon Zone has a complex Precambrian stratigraphy, including abundant felsic volcanic sequences, and it was intruded by numerous late Precambrian granitoid plutons. 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 it 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 latest events in the region, including alkalic plutonism, were contemporaneous with the rift-drift transition defined on the opposite (Laurentian) margin, and preceded deposition of Paleozoic cover rocks.

Paleozoic plutonic rocks are also present within the Avalon Zone, particularly along its western margin. As discussed above, the large Ackley Granite pluton straddles the Gander–Avalon boundary. Small epizonal plutons and spatially associated felsic volcanic rocks in southern Newfoundland were originally considered to be Carboniferous, but are now precisely dated as Devonian. There are no known Silurian granites in the Newfoundland Avalon Zone, although some mafic sills emplaced in Cambrian sedimentary rocks are dated at ~441 Ma. However, there are no pre-Devonian linkages across the Gander–Avalon boundary.

The south coast of Newfoundland contains late Precambrian rocks that are analogous in age and composition to those of the Avalon Zone (*sensu stricto*) and this region is now commonly grouped with the Avalon Zone in regional subdivision (Figure 1.2). However, the exact relationship between these rocks and those of the type area, and between both areas and the scattered late Precambrian enclaves within the eastern Dunnage Zone, is not well established. Some workers (e.g., Kerr *et al.*, 1995) have suggested that an isotopically distinct Precambrian basement terrane forms the substrate to the eastern part of the Dunnage Zone and the Gander Zone, and similar arguments have been advanced in Nova Scotia and New Brunswick (e.g., Barr *et al.*, 1998). Van Staal (2005, *in press*) extends this reasoning by defining Ganderia as a discrete terrane (see above, and later discussion of models).

In Newfoundland, the Gander–Avalon boundary (the Dover–Hermitage fault zone) is a first-order structure across which there are fundamental contrasts in geological history and metamorphic grade. In northeastern Newfoundland, the Dover Fault is associated with mylonites and shear zone development in Silurian granitoid rocks. However, the actual contact between the gneisses and grantoid rocks and the low-grade rocks of the Avalon Zone is a later brittle structure. A similar late brittle fault zone also defines the Gander–Avalon boundary in southern Newfoundland, where the earlier history of the zone is less well understood. The Dover–Hermitage fault zone was formerly viewed as a crustal-scale boundary along which the Avalon Zone was juxtaposed with the rest of the orogen during the Devonian, but the recognition of late Precambrian rocks in central Newfoundland and along the south coast (see above) blurs this simple interpretation. If the late Precambrian basement of these latter areas is a *direct* continuation of the Avalon Zone, the Dover–Hermitage fault zone must be less significant than previously thought. However, if late Precambrian rocks west of the Dover–Hermitage fault zone represent a discrete Precambrian terrane (van Staal, 2005, *in press*), then the boundary could still be of fundamental importance. However, unlike some other major structures within the Newfoundland Appalachians, the Dover–Hermitage fault zone lacks ultramafic rocks or dismembered ophiolite suites that might indicate the former presence of oceanic crust.

MEGUMA ZONE

The Meguma Zone is present only in eastern and southern Nova Scotia (Figure 1.2) and is not discussed in detail here; this short account is summarized from Van Staal (2005). The Meguma Zone is dominated by an Eocambrian to Early Ordovician sedimentary sequence, consisting almost entirely of turbidites. Sparse paleontological data and detrital zircon patterns indicate a Gondwanan source region, but the exact position within plate reconstructions is not known. The turbidites of the Meguma Supergroup are overlain disconformably by Late Ordovician to Devonian sequences, which are dominated by shallow-marine sedimentary rocks, but also include some bimodal volcanic rocks of Early Silurian age. The Meguma Zone contains abundant plutonic rocks of Devonian and Carboniferous age, and the major episodes of deformation, plutonism and metamorphism between 395 and 350 Ma correspond to the Acadian Orogeny. The Ordovician and Silurian events that dominate tectonic evolution in Newfoundland are apparently not recorded in the Meguma Zone, implying that its accretion to the rest of the Appalachian Orogen was relatively late.

LATE PALEOZOIC AND MESOZOIC DEVELOPMENT

Late Devonian and Carboniferous rocks are very widespread in the Atlantic provinces, but in Newfoundland they are restricted to small fault-bounded basins (Figures 1.2 and 1.3). The Bay St. George Basin (Knight, 1983) and the Deer Lake Basin (Hyde, 1979) are the largest, and extend into the offshore regions of the Gulf of St. Lawrence and White Bay, respectively. A small Carboniferous basin is present beneath Red Indian Lake in central Newfoundland, and Carboniferous rocks also occur in southeastern Newfoundland west of the Gander–Avalon boundary (Figure 1.3). Generally, Carboniferous sequences in Newfoundland consist of non-marine siliciclastic rocks in their lower parts, overlain by more varied but generally nonmarine sedimentary rocks including red beds, conglomerates, minor carbonate rocks, thin coal measures and evaporites, locally accompanied by mafic flows.

The boundaries of these major Carboniferous outliers are mostly faults, which appear to have also controlled sedimentation within the basins. The Carboniferous basins are thus interpreted as pull-apart structures developed along major strike-slip fault systems; local tight folding and thrusting of older rocks over the Carboniferous likely reflects continued strike-slip motions along these controlling structures. By inference, other major fault systems subparallel to regional strike in Newfoundland likely also were sites of Carboniferous strike-slip motions, but the magnitudes of such displacements are not known.

No Permian rocks are known in Newfoundland, and Mesozoic rocks are restricted to small intrusions and dyke swarms in Notre Dame Bay and on the Avalon Peninsula; the latter are considered to be related to the opening of the modern Atlantic Ocean.

PLATE TECTONIC MODELS FOR THE NEWFOUNDLAND APPALACHIANS

Early Models and the Development of Ideas

Models for the evolution of the Appalachian–Caledonian orogenic belt based upon continental drift first appeared in the late 1960s, and modern ideas can be traced back to *"Did the Atlantic close and then re-open?"* (Wilson, 1966). This paper first outlined the idea of discrete Laurentian and Gondwanan margins to the belt, and proposed that the region between these two margins consisted of a series of ancient island arcs that formed within the "Lower Paleozoic Atlantic Ocean", which would later be renamed the *Iapetus Ocean*. This basic framework remains unchanged, although far more detailed reconstructions of the birth and death of the Iapetus Ocean have been proposed over the last 40 years.

Two early plate tectonic models for the Newfoundland Appalachians were published almost simultaneously. Both proposed that the volcanic and sedimentary rocks of the Dunnage Zone formed an island-arc system within the Iapetus Ocean, but Dewey and Bird (1971) proposed subduction to the northwest (i.e., towards Laurentia) whereas Church and Stevens (1971) proposed subduction to the southeast (i.e., away from Laurentia). The model of Church and Stevens (1971) became the starting point for most subsequent ideas because it provided an explanation for the transported ophiolites of western Newfoundland, i.e., they were emplaced as a consequence of the attempted subduction of Laurentia beneath the island arc(s), which was followed by isostatic rebound of the less-dense continental crust. These early models also became the basis for the first attempts to relate mineral deposits in the Newfoundland Appalachians to various plate-tectonic environments (e.g., Strong, 1974). The rapid growth of the scientific database in the late 1970s and early 1980s soon led to the realization that there must be fragments of several different island-arc systems within the Dunnage Zone. At the same time, the concept of "suspect terranes" was developed in order to explain the geology of western North America, in turn suggesting that the Appalachian Belt could be a similar tectonic collage (Williams and Hatcher, 1983). It is now generally accepted that the early Paleozoic Iapetus Ocean probably had more similarities to the modern Pacific Ocean than to the modern Atlantic Ocean, i.e., it was a very complex environment littered with island arcs, seamounts and oceanic plateaux (e.g., Van Staal *et al.*, 1998). The rapid development and application of precise U–Pb zircon geochronology in the 1980s and 1990s finally provided the tools to construct and test more detailed tectonic models in which the steps are measured in increments of 10 million years or less, rather than several tens of millions of years. Not surprisingly, this increase in temporal resolution created a need for ever-more-complex models !

Space does not permit a detailed review of all plate tectonic models proposed for the Newfoundland Appalachians and surrounding areas since 1980, and many such models are relevant only to limited areas of the belt, or short time-slices in its development. It is only in recent years that truly integrated models covering the entire period from the latest Precambrian to the Carboniferous across the northern Appalachians have been proposed. The model outlined below, taken from work by Van Staal (2005, *in press*) is the most recent and possibly the most detailed to date, but some of its conclusions remain controversial. The model is depicted in a simplified manner by a series of cartoons (Figure 1.4). As with any plate tectonic model of this genre, many of its details remain speculative and some are keenly disputed. The following summary of this model does not imply that the authors agree with all of its details, but it should provide a framework for lively discussions during the field trip!

Late Precambrian–Middle Cambrian
(615 - 510 Ma)

The evolution of the Laurentian margin commenced ~615 Ma with rift-related igneous activity, including mafic dykes and minor alkaline granites in the Humber Zone. By about 570 Ma, the Iapetus Ocean was beginning to open, and the earliest siliciclastic sedimentary rocks of the passive margin sequence were deposited (Figure 1.4, part A). Waldron and Van Staal (2001) propose that this Cambro-Ordovician passive margin sequence developed within an elongate basin (termed the *Humber Seaway*) that was separated from the Iapetus Ocean proper by a discontinuous ribbon-like belt of Laurentian crust, termed the Dashwoods Microcontinent, which had been rifted away from Laurentia proper during the earlier stages of margin development. Direct evidence for such a microcontinent is scanty, and its existence is inferred mostly through continental isotopic signatures in some volcanic rocks of the eastern Dunnage Zone (see below).

The continental blocks termed *Ganderia* and *Avalonia*, consisting mostly of late Precambrian "Pan-African" crust, had also separated from Gondwana over the same general period, but their

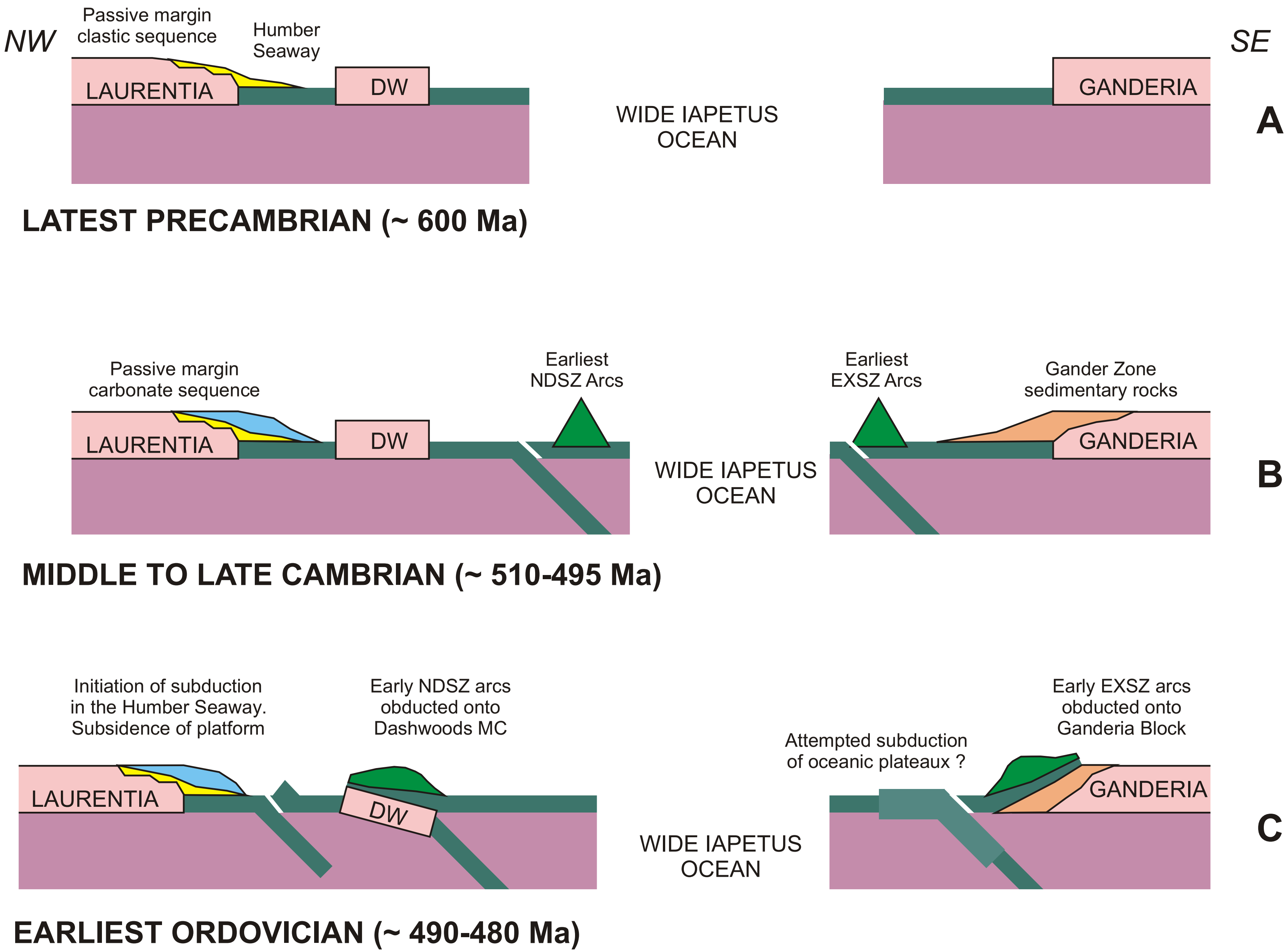


Figure 1.4: *Schematic cartoons showing a plate tectonic evolutionary model for the northern Appalachians, including Newfoundland. The model is summarized and simplified from Van Staal (2005, in press). See text for discussion of individual stages in the model portrayed in panels A to I.*

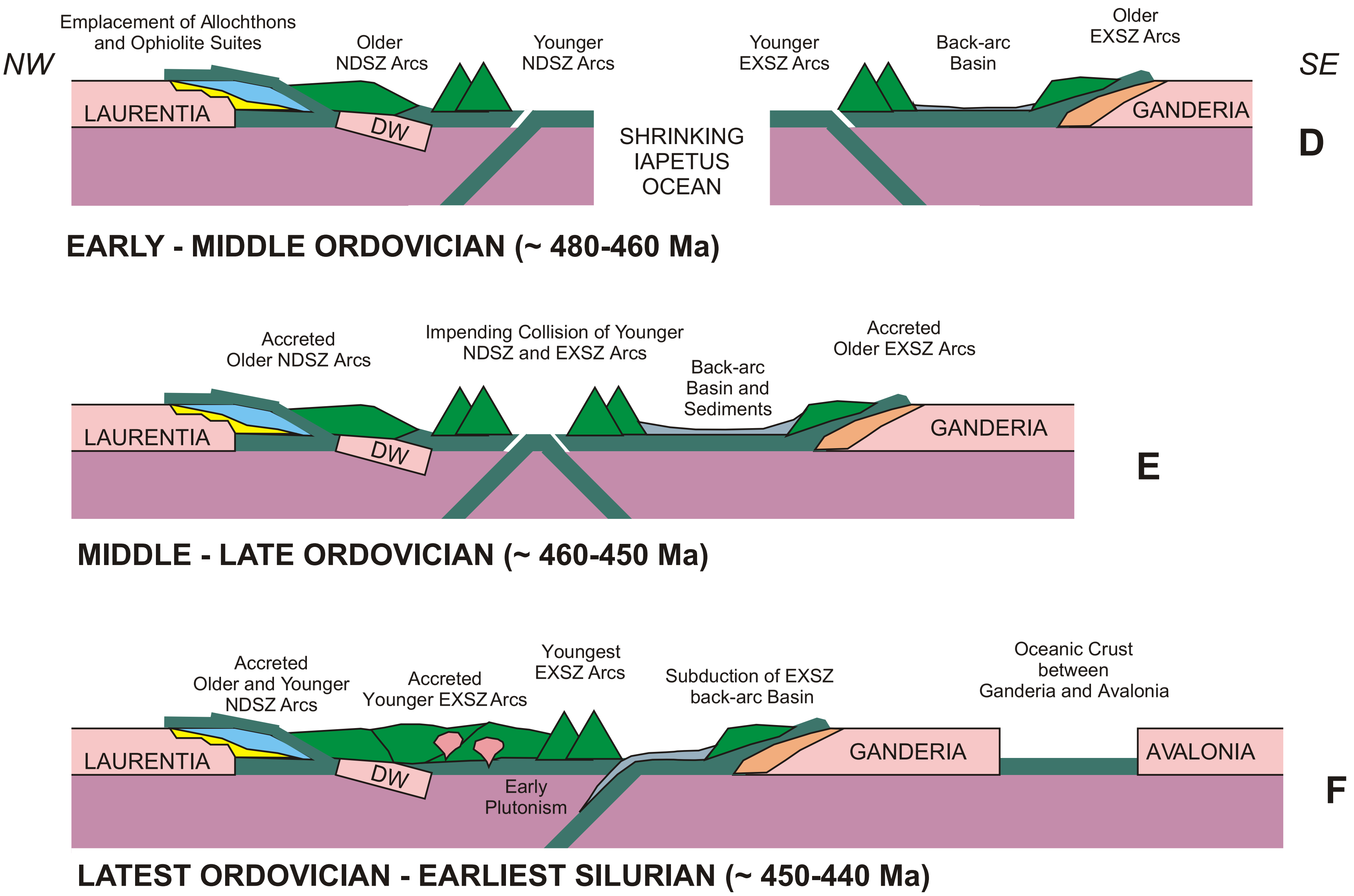


Figure 1.4: *Continued.*

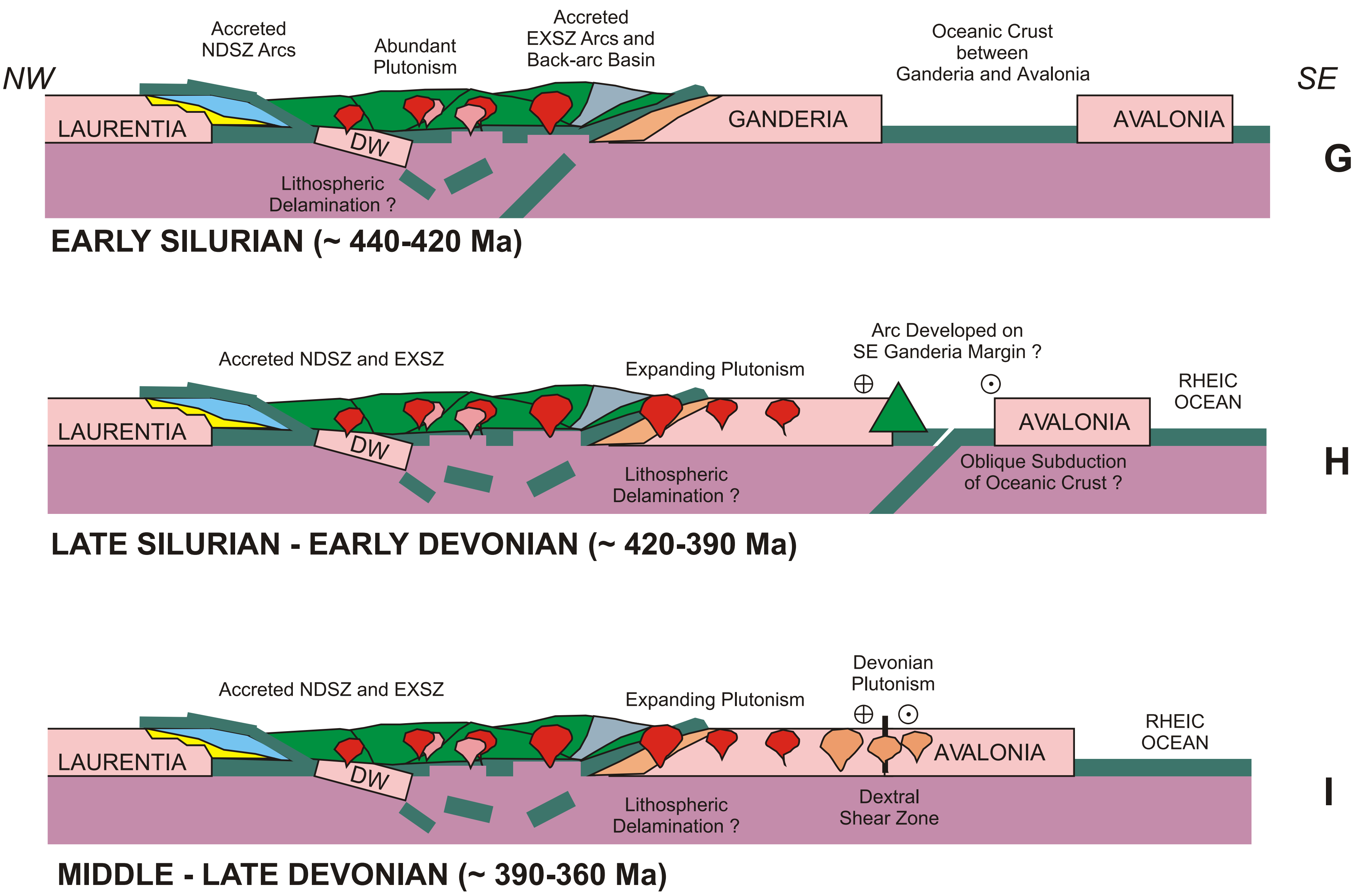


Figure 1.4: *Continued.*

positions relative to Laurentia (and to each other) over this period remain uncertain. However, the Iapetus is assumed to have been a wide oceanic basin. The presence of late Precambrian volcanic rocks in some parts of the Exploits Subzone suggests that there may have been some arc-related magmatism on the margin of Ganderia during the late Precambrian, but the nature of these events is uncertain, and no attempt has been made to depict these events in Figure 1.4. Similarly, some of the youngest Precambrian plutonic and volcanic rocks of the Avalon Zone formed within the same time period as the initial rifting of the Laurentian margin. The complete integration of the late Precambrian development of these Gondwanan regions into broad tectonic models for the Appalachian–Caledonian belt is a challenge for future models!

Middle to Late Cambrian (510 - 490 Ma)

During this time period, the overall architecture of the Laurentian margin resembles that described above for the preceding interval (Figure 1.4, part A). The carbonate sequence of the passive margin sequence continued to accumulate. However, the situation began to change within the Iapetus Ocean, where an island arc was now active, fairly close to the Laurentian margin, above a southeast-dipping subduction zone (Figure 1.4, part B). These rocks are now preserved as some of the oldest volcanic sequences along the western edge of the Notre Dame Subzone, notably the Lushs Bight, Cutwell and Moretons Harbour groups.

A wide stretch of the Iapetus separated the Laurentian margin from the opposing Gondwanan margin, but the northwest margin of Ganderia was also a site of island-arc magmatism by the Middle Cambrian. Van Staal (2005, *in press*) suggests that southeast-directed subduction led to eruption of the oldest volcanic rocks within the Exploits Subzone, notably the Tally Pond volcanics, although earlier models (e.g., Van Staal, 1994) suggest that subduction was in the opposite direction, in order to account for the subsequent obduction of ophiolites. The presence of late Precambrian inliers in the Exploits Subzone suggests that these volcanic rocks were, in part, built upon a continental substrate, as shown in Figure 1.4, part B.

Earliest Ordovician (490 - 480 Ma)

This time period corresponds to the earliest stages of the Taconic Orogeny on the Laurentian margin and to the Penobscot Orogeny on the opposing margin. Continued southeastward subduction beneath the island arc closest to Laurentia eventually led to attempted subduction of Laurentia and/or the Dashwoods Microcontinent beneath the arc (Figure 1.4, part C). The continued convergence of the island arcs and the main part of Laurentia was accommodated in some areas by short-lived subduction within the Humber Seaway, which led to the emplacement of deep-water sedimentary rocks and eventually slices of relatively young oceanic crust above the passive margin sedimentary sequence. Elsewhere, older Iapetan crust was emplaced directly onto the Laurentian margin, perhaps because the Dashwoods microcontinent was discontinuous. These events were recorded by the foundering and collapse of the carbonate platform, and its transformation into a foreland basin, which then received flysch derived from the approaching allochthons prior to their actual arrival at a later time (Stevens, 1970, Williams and Stevens, 1974).

On the opposing margin of the Iapetus Ocean, the earliest island-arc volcanic rocks of the Exploits Subzone were emplaced over the sedimentary sequence now represented by the metasedimentary rocks of the Gander Zone. Van Staal (2005, *in press*) speculates that oceanic crust was obducted onto the Ganderia margin as a consequence of attempted subduction of seamounts and oceanic plateaux. Previous models (e.g., Van Staal, 1994) had suggested that the polarity of subduction in this area was opposite to that illustrated, and that obduction recorded the attempted northwestward subduction of continental crust. The separation of Laurentia from the opposing margin at this time is not known, but Van Staal (2005, *in press*) suggests that the two were still as much as four thousand kilometres apart.

Early and Middle Ordovician (480 - 460 Ma)

The Middle Ordovician was an important period of subduction on both sides of the Iapetus Ocean, and many island-arc volcanic rocks in the Dunnage Zone of Newfoundland were generated during this time period. It is also the time during which the Taconic allochthons underwent final emplacement across the passive margin sequence, overriding their own flysch deposits in the process.

On the Laurentian margin, there was a reversal of subduction polarity following attempted subduction of the Dashwoods Microcontinent, and Middle Ordovician island arcs were built upon a substrate of previously accreted Cambrian and earliest Ordovician arcs, together with fragments of Laurentian basement (Figure 1.4, part D). The younger arcs include the so-called “mature arc” sequences of the Buchans and Roberts Arm groups of central Newfoundland, which contain calc-alkaline mafic volcanics and felsic volcanic centres. Buried continental crust of the Dashwoods Microcontinent may have contributed to some of these magmas, as their isotopic signatures are locally evolved. Distal products of this northwest-directed subduction may include plutonic rocks emplaced within the older arc sequences and Laurentian continental crust to the northwest.

On the opposing margin, a remarkably similar situation existed. Renewed (or continued) southeast-directed subduction led to the formation of island arcs built upon older arcs and/or late Precambrian basement. In Newfoundland, these are represented mostly by younger rocks within the Victoria Lake Supergroup, dominated by calcalkaline basalts and felsic rocks. Behind this arc system, a back-arc basin opened up, and this was filled with detritus, both from the arc and from continental sources to the east (Figure 1.4, part D). This back-arc basin is best preserved in New Brunswick, although it may have extended into the Exploits Subzone of Newfoundland, accounting for the more complete Late Ordovician into Silurian sedimentary record of the Exploits Subzone compared to that of the Notre Dame Subzone.

During the period between 480 Ma and 460 Ma, the remaining oceanic crust of the Iapetus was rapidly consumed by subduction on both margins. Van Staal (2005, *in press*) suggests that this phase of development was terminated by an arc-arc collision about 454-450 Ma ago, roughly along the present Red Indian Line.

Middle and Late Ordovician (460 - 450 Ma)

During the later Ordovician, the main part of the Iapetus Ocean closed completely, and the island arc adjoining Ganderia was accreted to Laurentia along the composite structures now known as the Red Indian Line (Figure 1.4, part E). The leading edge of Laurentia at this time became the arc terranes that originally formed on the opposite Gondwanan margin. However, the back-arc basin located between this island arc and Ganderia still existed. Van Staal (2005, *in press*) further suggests that a region of oceanic crust also existed on the other side of the Ganderia block, separating it from Avalonia proper. However, it is also possible that Ganderia and Avalonia had formed a single continental block since the late Precambrian (see below).

Latest Ordovician–Earliest Silurian
(450 - 440 Ma)

Following the accretion of the arcs to Laurentia in the Late Ordovician (Figure 1.4, part E), northwestward subduction resumed beneath the new leading edge of Laurentia, and the back-arc basin that originally lay southeast of the arc was consumed, and its sedimentary fill was deformed (Figure 1.4, part F). This subduction activity is supposedly recorded by plutonism across all the previously accreted Laurentian and

Gondwanan arc terranes to the northwest. The closure of the back-arc basin corresponds to the earliest stages of the Salinic Orogeny, which is the dominant deformational event across Newfoundland.

Early Silurian (440 - 420 Ma)

By the Early Silurian, the Ganderia continental block had been accreted to Laurentia following closure of the back-arc basin, and the leading edge of Laurentia consisted of continental crust of Gondwanan affinity. This was a period of intense plutonism across much of the region, and also saw the development of felsic volcanic centres and caldera complexes across previously accreted arc terranes, and even into the Humber Zone (Figure 1.4, part G). Some of these Silurian magmas may record the waning stages of subduction, whereas others may record uplift of the orogen and lithospheric delamination. The older Cambrian and Ordovician rocks were uplifted and eroded, particularly in the west, where there is a profound sub-Silurian unconformity. The collision of Ganderia and Laurentia was the driving force for Salinic deformation and metamorphism, which also extended as far as the eastern part of the Humber Zone. Compressional deformation was widespread, such that continental crust of either Laurentian or Gondwanan affinity now underlies all of the Dunnage Zone (not shown in Figure 1.4 for reasons of clarity).

The relationship between Ganderia and Avalonia becomes an issue during the Silurian, and there are two end-member possibilities. If the late Precambrian rocks of both regions are one and the same, then Ganderia and Avalonia formed a single continental block that was accreted to Laurentia at this time. If, on the other hand, they were still separate entities, some oceanic crust may have remained between Ganderia and Avalonia. Van Staal (2005, *in press*) suggests that a narrow oceanic tract remained between Ganderia and Avalonia (Figure 1.4, part G). If the latter interpretation is correct, the consumption of this remaining oceanic crust by northwest-directed subduction may also be an integral part of the Salinic Orogeny (see below).

Late Silurian and Early Devonian (420 - 390 Ma)

The model of Van Staal (2005, *in press*) suggests that the oceanic crust that remained between the leading edge of Laurentia (now represented by Ganderia) and Avalonia was consumed by oblique northwest-directed subduction in the Late Silurian and earliest Devonian (Figure 1.4, part H). The extensive Silurian granitoid rocks of the Gander Zone and south coast region in Newfoundland may represent products of such processes, and there are some bimodal volcanic rocks of appropriate age elsewhere in the Atlantic Provinces, notably in in New Brunswick. However, there are few volcanic rocks of this age in eastern Newfoundland, although Van Staal (2005, *in press*) suggests that Silurian sequences along the south coast may be part of this arc system. The Gander–Avalon boundary in Newfoundland is a sharp break that is, in part, associated with a major dextral shear zone, and later motions along it may have excised rocks that originally lay between the two.

Middle and Late Devonian (~390-360 Ma)

The accretion of Avalonia to composite Laurentia was followed by continued granitic plutonism, notably along their mutual boundary and associated with the widespread deformation assigned to the Acadian Orogeny. In Newfoundland, the Avalon Zone was certainly juxtaposed with the Gander Zone by about 380 Ma, although the collision of the two may have been earlier. Farther to the west, granitic plutonism was waning by the Devonian, although some isolated examples were generated (Figure 1.4, part I).

Carboniferous (post-360 Ma)

The post-Devonian evolution of the orogen in Newfoundland is largely one of strike–slip motions along major fault systems, and the development of Carboniferous pull-apart basins. This period is not represented in Figure 1.4. Similarly, no attempt is made here to discuss the Devonian or Carboniferous accretion of the Meguma Zone in Nova Scotia, or the Devonian and Carboniferous events recorded in the southern part of the Appalachians.

REGIONAL METALLOGENY OF NEWFOUNDLAND

Section 2 of this guide provides an overview of gold mineralization in Newfoundland, and subsequent sections provide details of the field excursion. This short summary provides an overview of regional metallogenic patterns in the Newfoundland Appalachians and surrounding areas. It is drawn mainly from review papers, notably Swinden and Dunsworth (1995), Swinden *et al.* (2001), Evans (2001a) and Van Staal (*in press*). It also draws upon short reports intended to summarize various commodities, such as Ni (Kerr, 2000), Zn and Cu (Wardle, 2000a, b), and Au (Wardle, 2005). References to individual examples and studies are contained within these review articles.

The island of Newfoundland hosts a wide variety of mineral occurrences, including base metals, precious metals, iron ores, rare metals, uranium, antimony and a range of industrial minerals including gypsum, fluorite, asbestos, talc, pyrophyllite, fluorite and dimension stone. Most, if not all, these commodities have been produced at some point in the history of the island. Newfoundland metallogeny is logically treated according to the tectonic zones outlined above, and can be related in general terms to the various steps in tectonic evolution discussed in the previous section.

Humber Zone

The Precambrian basement rocks of the Humber Zone contain few mineral occurrences. Anorthositic rocks in the Stephenville area have produced iron ores in the form of magnetite, and the anorthositic rocks of the Steel Mountain Intrusion (Figure 1.3) locally contain Ni-poor magmatic sulphide mineralization. The Long Range Inlier is mostly devoid of mineralization, except in its southeastern corner.

The Cambro-Ordovician platformal rocks in the Humber Zone contain important Zn–Pb–Ba mineralization, notably at the Daniel’s Harbour deposit, which contained some 6.6 Mt at 7.9% Zn. Smaller prospects also occur elsewhere along the west coast of the island. These are Mississippi-valley-type Pb–Zn deposits, and the mineralization is epigenetic with respect to their host rocks. Fluids are believed to have been expelled from deep-water sedimentary rocks during Middle Ordovician emplacement of Taconic allochthons, with sulphide deposition in older host units that gained porosity due to paleokarst weathering and/or dolomitization. Minor Pb and Zn mineralization of similar aspect is known in thin carbonate units of the Silurian Sops Arm Group, but this may be of Carboniferous age, derived from the nearby Deer Lake Basin.

Other mineral occurrences in the Humber Zone include uranium in Carboniferous sandstones in the Deer Lake area, and numerous industrial minerals deposits, mostly limestone, dolostone, marble, gypsum, halite and minor coal seams. The Humber Zone is also believed to have significant petroleum potential in both Cambro-Ordovician and Carboniferous sedimentary rocks. Small oil discoveries have been made in both settings, but major producing oilfields have yet to be identified.

Gold mineralization is rare, but it is present in Cambrian sedimentary rocks and Precambrian granites in the White Bay area, and also within Silurian volcanic and sedimentary rocks of the Sops Arm Group. This is described in the following sections.

Dunnage Zone

The Dunnage Zone contains, by far, the largest number of mineral deposits in Newfoundland and was the site of some of the first mining ventures in the province, notably for copper. The metallogeny of the Dunnage Zone is very much dominated by base metals (Cu, Zn, Pb) and precious metals (mostly Au), although other commodities are present locally.

Base-metal deposits in the Dunnage Zone are mostly volcanogenic massive sulphide (VMS) deposits and related stockwork-type mineralization. These occur almost exclusively in island-arc and back-arc basin volcanic sequences of Cambrian to Ordovician age. The deposits range from true exhalative seafloor sulphides and subseafloor replacement deposits to transported debris-flow ores. All these deposits are essentially syngenetic with respect to their host rocks. Smaller deposits of epigenetic character are likely stockwork-style feeder systems and alteration pipes that form part of larger syngenetic systems. The VMS deposits range from Cu-rich, sometimes with associated Au, to polymetallic deposits containing Cu, Zn, Pb, Au and Ag, commonly with associated Ba. The largest and richest VMS deposit was Buchans in central Newfoundland, which contained 16 Mt of 14.5% Zn, 7.6% Pb, 1.3% Cu, 126 g/t Ag and 1.4 g/t Au. Buchans was also the province's largest Au producer to date, yielding some 22 tonnes. Generally, deposits associated with mafic-dominated tholeiitic volcanic sequences are Cu-rich, whereas those associated with calcalkaline volcanic sequences including felsic centres tend to be polymetallic. In addition to the VMS deposits of the Dunnage Zone proper, minor VMS mineralization is also present in the transported ophiolites of the Bay of Islands area. As discussed in Section 2, many VMS deposits were important sources of gold.

Dunnage Zone ophiolites host deposits of talc and asbestos, including the large Advocate asbestos deposit, and also contain podiform chromite concentrations. Minor Ni mineralization of hydrothermal character was associated with the Tilt Cove VMS deposit, and some small magmatic sulphide occurrences are also known. A significant antimony deposit occurs in Silurian sedimentary rocks of the Exploits Subzone, and has seen sporadic production when prices permitted. Arsenic was mined in a few places around Notre Dame Bay, and both granite and gabbro have been quarried for dimension stone in several different areas. The plutonic rocks of the Dunnage Zone contain relatively few mineral occurrences, but minor Mo and W mineralization is locally present in association with Siluro-Devonian granitoid rocks in the Granite Lake area of south-central Newfoundland.

The Dunnage Zone also contains innumerable gold occurrences. Two such deposits have produced gold over the last 10 years, whereas others await production decisions. The majority of these gold occurrences are hosted by the same volcanic sequences that host the VMS mineralization, but the gold mineralization is epigenetic. There are relatively few gold occurrences in the Silurian volcanic and sedimentary rocks of the Dunnage Zone. The characteristics and affinities of this largely mesothermal Dunnage Zone gold mineralization are discussed in more detail in Sections 2 and 3.

Gander Zone

The Gander Zone is poorly endowed in metals compared to the adjacent Dunnage Zone, but it does contain some epigenetic gold mineralization of both mesothermal and epithermal character. This mineralization is discussed in more detail in Sections 2 and 3. Some minor granite-related mineralization (Mo, W and Be in pegmatites) is known in the Bonavista Bay area, in south-central Newfoundland, and along the island's south coast. This latter region, although considered by some to be an extension of the Avalon Zone, has many geological similarities to the Gander Zone. Mineral deposits in this area include the Hope Brook gold mine, which contained 10.2 Mt of 4.5 g/t Au. There are also W-bearing veins in the Grey River area, which may have potential for associated Au. Both are discussed in more detail in Section 2.

Avalon Zone

Several types of Precambrian and Paleozoic mineralization occur within the Avalon Zone, and correlative rocks on the south coast of Newfoundland. Small VMS deposits occur within ~680 Ma submarine volcanic sequences of the western Avalon Zone. Calcalkaline plutonic rocks of ~620 Ma age host minor Cu–Mo mineralization believed to be of porphyry type. Latest Proterozoic sedimentary rocks of the Bonavista and Burin peninsulas contain disseminated stratiform Cu mineralization, largely in the form of chalcocite. This mineralization resembles that known from world-class redbed copper districts such as the Zambian copper belt, and has attracted industry attention. Late Precambrian alkaline granites of the Cross Hills Suite in southern Newfoundland contain disseminated Zr–Nb–REE mineralization.

Paleozoic mineralization in the Avalon Zone includes “Clinton-type” oolitic hematite deposits at Bell Island, near St. John’s, hosted by Ordovician sedimentary rocks. These were important iron ore sources for almost 100 years, but are currently dormant, despite resources that total billions of tons. Epigenetic granite-related mineralization associated with the Devonian St. Lawrence granite of the southern Burin Peninsula is dominated by fluorite veins, but also includes minor Pb and Zn mineralization. Molybdenite, and some associated Sn mineralization, is hosted by evolved pegmatitic and aplitic phases of the Devonian Ackley Granite in southern Newfoundland. Vein-hosted Pb, Ag and Ba mineralization also occurs in the Placentia Bay area, where it may be associated with a buried Devonian (?) plutonic body. Industrial minerals exploited in the Avalon Zone include pyrophyllite (near St. John’s) and slate in the Bonavista Bay area.

Late Precambrian volcanic sequences all across the Avalon Zone host Au mineralization of broadly epithermal type, developed broadly synchronously with the host rocks. No major deposits have to date been identified, but there has been significant industry interest in this unusual example of fossil epithermal systems. This gold mineralization is described in more detail in Sections 2 and 3, and in a separate guide by O’Brien *et al.* (2005).

SECTION 2: AN OVERVIEW OF GOLD MINERALIZATION IN NEWFOUNDLAND

(R.J. Wardle and A. Kerr)

INTRODUCTION

General Information

This section of the guidebook provides an overview of gold mineralization environments currently recognized in Newfoundland. More detailed information concerning specific areas of Newfoundland, individual deposits and field-trip stops is provided in Section 3. This section of the guidebook is essentially an expanded version of a review by Wardle (2005) forming part of the commodity series reports published by the Geological Survey. It draws also upon reports by Tuach *et al.* (1988), Evans (1999, 2001a, 2004), O'Brien *et al.* (1998, 1999), Kerr (2004, 2005) and Squires (2005). Readers should consult these articles for detailed reference lists and other information.

A Short History of Gold Exploration in Newfoundland

The island of Newfoundland has a long history of gold exploration, but it is only in the last 25 years that systematic exploration for Au has taken place. The first discoveries of gold were made in the late 1870s in the Mings Bight area of the Baie Verte Peninsula, and gold-bearing quartz veins were discovered near Brigus, Conception Bay, in 1880. In the early 20th century, the first attempts at mining Au took place near Mings Bight (the Goldenville Mine) and near Sops Arm in White Bay (the Browning Mine). Both deposits produced sporadically in 1903 and 1904, but these early attempts were not very successful, as the veins were quickly exhausted. Several other gold prospects were explored in the White Bay area and in other parts of Newfoundland, mostly on the shores of Notre Dame Bay, but there was no significant production. In 1935, the first geological report on gold mineralization in Newfoundland was published (Snelgrove, 1935), and provided details on 26 reported occurrences of gold, including the two early mines. There was little interest in or exploration for Au over the next 75 years, during which most of Newfoundland's mineral production consisted of iron ore, Cu, Zn and Pb. However, several of the major VMS deposits in Newfoundland did produce Au as a byproduct, notably the Buchans, Rambler and Tilt Cove deposits.

In 1976, significant gold mineralization was discovered near Cape Ray on the southwest coast of Newfoundland (Figure 2.1), and interest in gold exploration was revived, although the deposits proved subeconomic after underground exploration. This was followed in 1984 by the discovery of the Hope Brook deposit, also located near the southwest coast (Figure 2.1), which became the Province's first major gold producer in 1986. The mine operated until 1997, including a short period of dormancy during a change of ownership. The discovery of the Hope Brook deposit ushered in a surge of exploration for gold that was to last until about 1990. Financial incentives for investment in mineral exploration and development through the tax system at the time provided a major incentive for grass-roots exploration in Newfoundland, and gold prices were also high. Exploration efforts focused initially on dismembered ultramafic belts in northwestern Newfoundland (following analogies with the Californian Mother Lode deposits) and then broadened to include much of the Dunnage Zone of central Newfoundland. Numerous gold occurrences were documented across the Dunnage Zone, and also in parts of the Humber and Gander zones, and the number of mineralized localities exploded from 27 to nearly 200. Figure 2.1 shows only the most significant prospects amongst this large population. Two of these discoveries became producing mines several years later. The Nugget Pond Mine operated from 1997 to 2001, and was followed by the Hammerdown Mine, which operated from 2001 to 2004. The

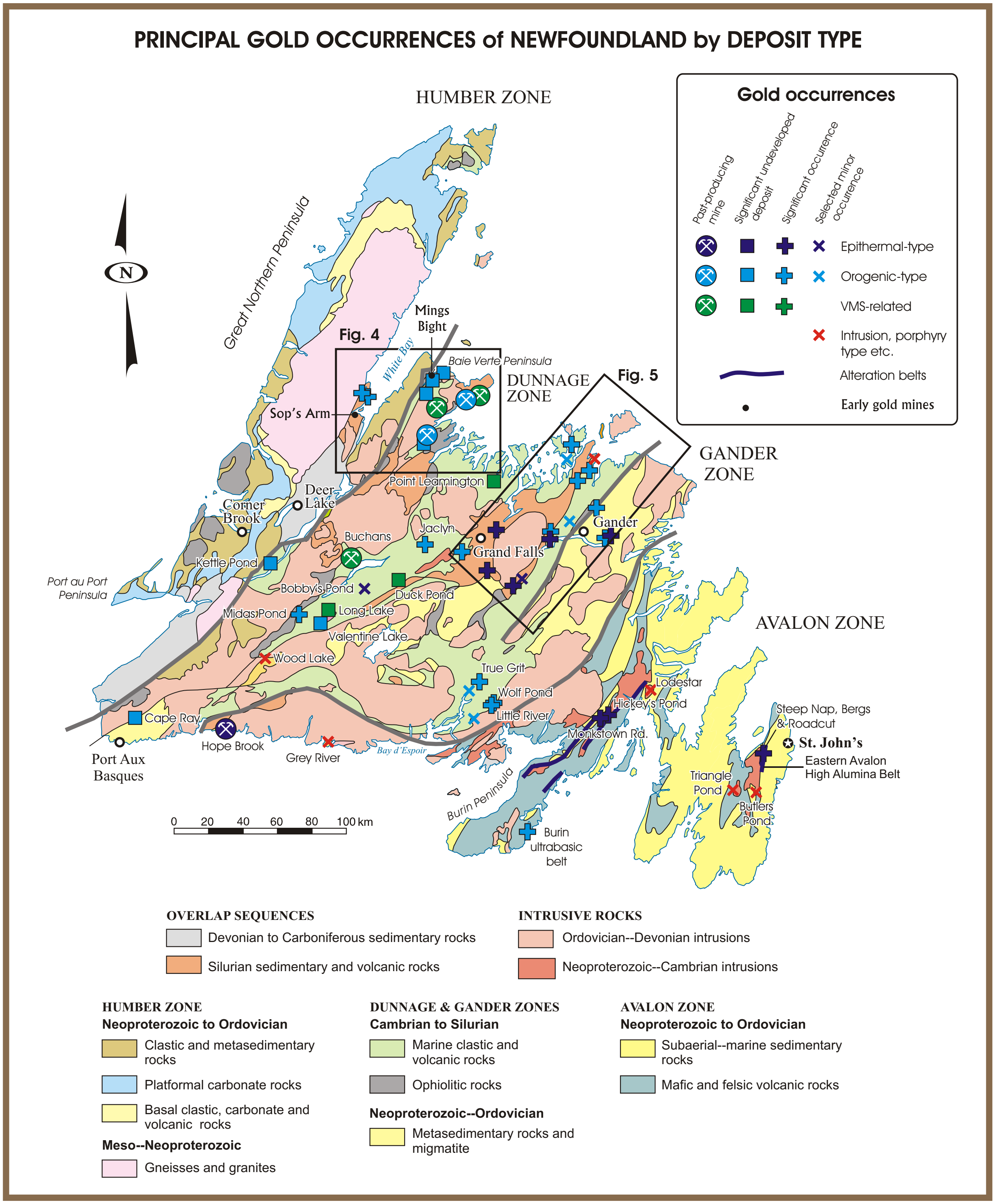


Figure 2.1: *Simplified geological map of Newfoundland showing important gold deposits. From Wardle (in press).*

Stog'er tight deposit produced briefly, but encountered problems with grade dilution. Other deposits outlined at this time, notably Pine Cove and Valentine Lake, represent potential production in future years. Gold mineralization was also discovered in several areas of the Avalon Zone, where it was previously unknown, and its epithermal character was noted.

Gold exploration waned as the gold price fell in the late 1990s and tax incentives for exploration were eliminated. A strong rebound in gold prices in 2002 led to a resurgence of exploration and reappraisal of many prospects discovered in earlier years. As of early 2005, gold prices remain healthy, and exploration is very active. Previously discovered deposits and prospects are all being re-investigated and several promising new grassroots discoveries have been made in the last few years. There has also been interest in the potential of certain areas to host large disseminated gold deposits of the "Carlin type" in addition to previously recognized vein-hosted and shear-zone-hosted mineralization.

Newfoundland has produced over 64 tonnes (~2 million ounces) of gold, about half of which has been derived as a by-product of base-metal mining. The Buchans VMS deposits of central Newfoundland account for some 22 tonnes, and several tonnes were produced from several other VMS deposits, notably Tilt Cove and Rambler (Table 2.1). The undeveloped Duck Pond and Point Leamington VMS deposits retain the largest undeveloped resource, and several other undeveloped VMS and gold-only deposits contribute the remainder (Table 2.1). Total undeveloped resources amount to some 40 tonnes, or about 1.3 million ounces.

Table 2.1: Tonnages, grades and gold inventories of former producers, and undeveloped gold deposits in Newfoundland. Adapted from Evans (2001a) and Wardle (in press)

Part 1: Gold production

Gold produced as a byproduct of base metal mining (mostly VMS deposits)

Area	**Time Period**	**Ounces**	**tonnes**	**%**
Notre Dame Bay area	pre-1917	164,000	5.25	7
Tilt Cove	1957-1961	42,000	1.35	2
Little Bay	1961-1969	6,000	0.19	<1
Buchans	1928-1984	713,000	22.84	34
Rambler	1964-1982	244,000	7.82	12
Total		1,169,000	37.46	55

Gold produced from gold-only deposits

Area	**Time Period**	**Ounces**	**tonnes**	**%**
Hope Brook	1987-1997	624,000	19.99	30
Nugget Pond	1997-2001	169,000	5.41	8
Hammer Down	2001-2004	143,000	4.58	7
Total		936,000	29.98	45

Part 2: Undeveloped gold resources

Gold as a possible byproduct of base metal mining (mostly VMS deposits)

Area	**Ounces**	**tonnes**	**Tonnage**	**oz/t**	**g/t**
Duck Pond	141,000	4.38	5,500,000	0.023	0.8
Rambler (Ming)	45,000	1.41	707,000	0.06	2.0
Rambler (Main)	19,000	0.60	104,000	0.17	5.8
Rambler (Footwall)	52,000	1.62	360,000	0.13	4.5
Point Leamington	79,000	2.46	1,600,000	0.04	1.5
Long Lake	16,000	0.51	560,000	0.03	0.9
Total	352,000	10.98			

Potential gold production from gold-only deposits

Area	**Ounces**	**tonnes**	**Tonnage**	**oz/t**	**g/t**
Orion	61,000	1.89	270,000	0.20	7.0
Cape Ray	121,000	3.76	455,000	0.24	8.3
Kettle Pond	19,000	0.60	175,000	0.10	3.4
Pine Cove	205,000	6.37	2,277,000	0.08	2.8
Deer Cove	18,000	0.56	94,000	0.17	6.0
Stog'er Tight	51,000	1.57	350,000	0.13	4.5
Valentine Lake	439,000	13.65	1,300,000	0.31	10.5
Total	914,000	28.40			

Environments of Gold Mineralization in Newfoundland

Several different types of gold mineralization are recognized in Newfoundland. A schematic model linking the various deposit types to crustal level and tectonic setting is shown in Figure 2.2, based upon the proposals of Poulsen *et al.* (2000).

As discussed above, VMS-related auriferous sulphide deposits made a very important contribution to past production and undeveloped resources. This mineralization is essentially syngenetic with respect to the host volcanic or sedimentary rocks. All other styles of gold mineralization are epigenetic, although some epithermal mineralization may be broadly contemporaneous with, or slightly younger than, host volcanism. The most common are mineralized quartz veins, vein swarms and wall-rock replacement bodies of broadly mesothermal character, a deposit type now commonly termed "orogenic gold" (e.g., Groves *et al.*, 1998, Poulsen *et al.*, 2000; Goldfarb *et al.*, 2001). This mineralization is regionally associated with important structural lineaments. Most mineralization in the Dunnage Zone falls into this broad category, and the various subtypes identified in Figure 2.2 are all documented. Gold mineralization of epi-

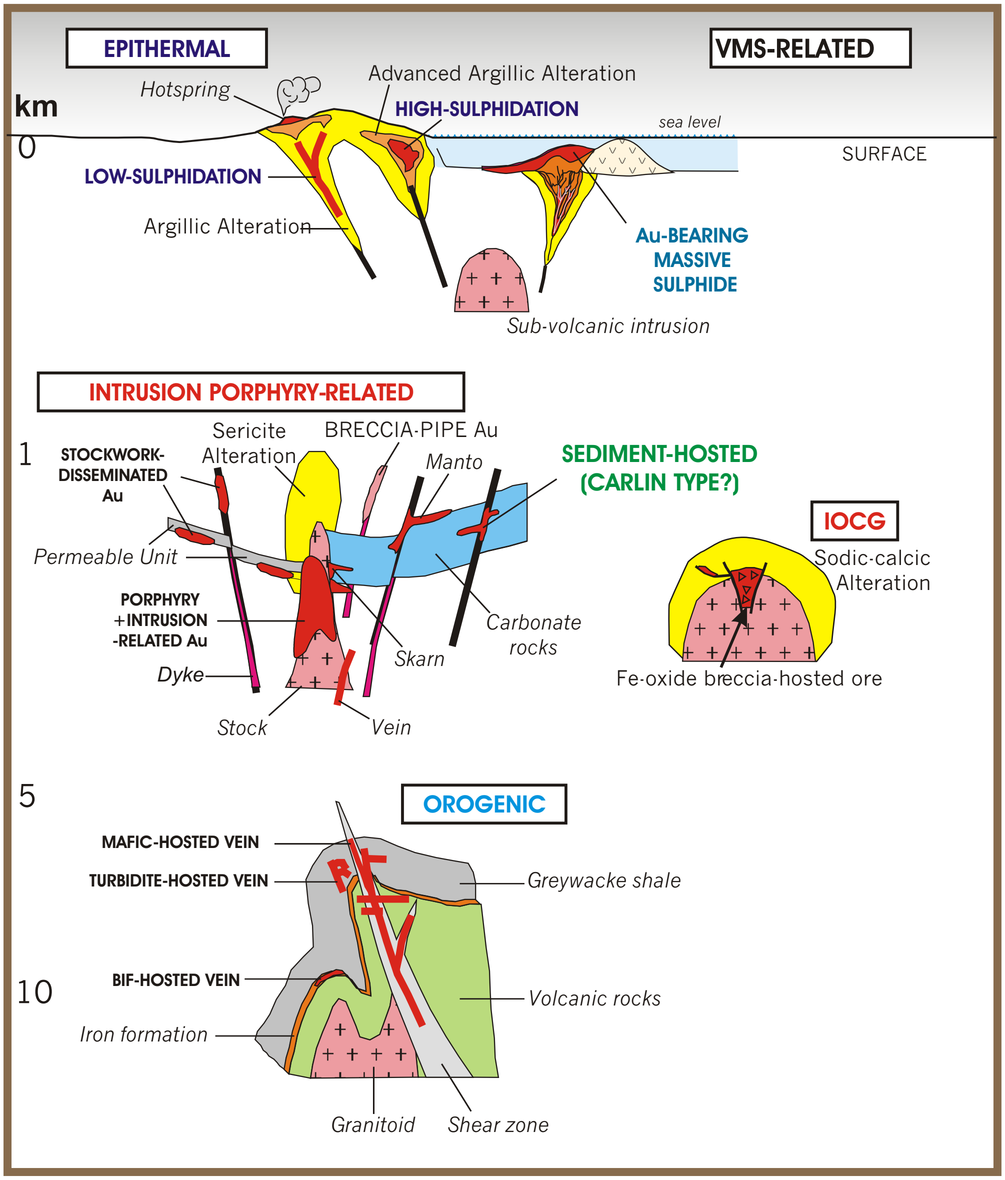


Figure 2.2: *Styles and environments of gold mineralization, after Poulsen et al. (2000).*

thermal type, formed at high structural levels compared to these mesothermal vein systems, dominates within the Avalon Zone, and is increasingly recognized in central Newfoundland, notably in the eastern Dunnage Zone. Gold mineralization hosted by or associated with granitoid intrusive rocks is not well documented, but there are some possible examples on the south coast of Newfoundland. In the Humber Zone of western Newfoundland, disseminated to stockwork-style gold mineralization occurs in Precambrian granites and adjacent Cambro-Ordovician sedimentary rocks, and is possibly of "Carlin type", although it shares some attributes of orogenic gold mineralization. This is described below in conjunction with the orogenic gold deposits.

AURIFEROUS VOLCANOGENIC MASSIVE SULPHIDE (VMS) ENVIRONMENTS

The locations of the main Au-bearing volcanogenic massive sulphide (VMS) deposits are shown in Figures 2.1 and 2.3. More detailed descriptions and additional locations of gold-poor VMS deposits are provided elsewhere (e.g., Swinden *et al.*, 2001; Wardle, 2000 a, b). The VMS deposits are subdivided into copper-rich ophiolite or primitive-arc settings, notably around Notre Dame Bay, e.g., the Tilt Cove and Little Bay deposits (Figure 2.3), and the polymetallic, mature-arc environments located on the Baie Verte Peninsula (e.g., the Rambler deposit; Figure 2.3) and inland parts of the Dunnage Zone (e.g., the Buchans and Duck Pond deposits, Figure 2.1). Buchans was the main producer of both base metals and gold, and produced 22.2 tonnes of gold from ores having an average grade of 1.37 g/t Au. Duck Pond is significantly smaller, but has comparable Au grades. The Rambler deposits also contained significant gold, notably in the Main and Ming mines and in the Main Mine footwall deposit (Table 2.1), which contains grades of around 4.5 g/t Au, and remains undeveloped below 200 m. Visible gold was commonly reported in deeper sections of the Ming Mine during the final days of mining at Rambler. The Point Leamington deposit, a large low-grade Zn-dominated VMS body (Figure 2.1), also contains significant Au concentrations, up to 1.5 g/t, in its higher-grade sections. The high price of gold and base-metals has rekindled interest in these deposit types. The Rambler deposit and the Colchester deposit (a small Cu-rich auriferous VMS near Springdale) are examples of active exploration projects (Figure 2.3).

EPITHERMAL ENVIRONMENTS

Epithermal-style gold mineralization in Newfoundland falls into two groups, namely Late Neoproterozoic examples in the Avalon Zone (Figure 2.1), and middle Paleozoic examples in central Newfoundland. Most known epithermal deposits belong to the first group, and are located in the Avalon Zone and temporally equivalent rocks on the south coast of Newfoundland. The second group is found in and around the Silurian rocks of the (so-called) Botwood basin, in the eastern Dunnage Zone (Figure 2.4). The Hope Brook Mine (Figure 2.1) on the south coast was the only producing deposit of this class in the Province. This was actually the largest deposit ever mined in the Canadian Appalachians and was the Province's second largest gold producer after Buchans. The deposit contained 41 tonnes of gold (about half of which was recovered) in a resource of 10.2 million tonnes grading 4.54 g/t and also containing significant amounts of copper (12 224 tonnes). It is considered to represent one of best examples of an epithermal high-sulphidation gold deposit in Canada (Dubé *et al.*, 1998). It is located on the hanging wall of a major shear zone within strongly deformed and metamorphosed Neoproterozoic sandstone and quartz-feldspar porphyry, and is dated precisely at between 578 and 574 Ma. Associated alteration is intense and consists of an internal zone of silicic alteration giving way to a broad external zone of argillic alteration (Dubé *et al.*, 1998).

Epithermal gold deposits in the Avalon Zone *sensu stricto* (O'Brien *et al.*, 1998, 1999) are found principally on the Burin Peninsula and in the

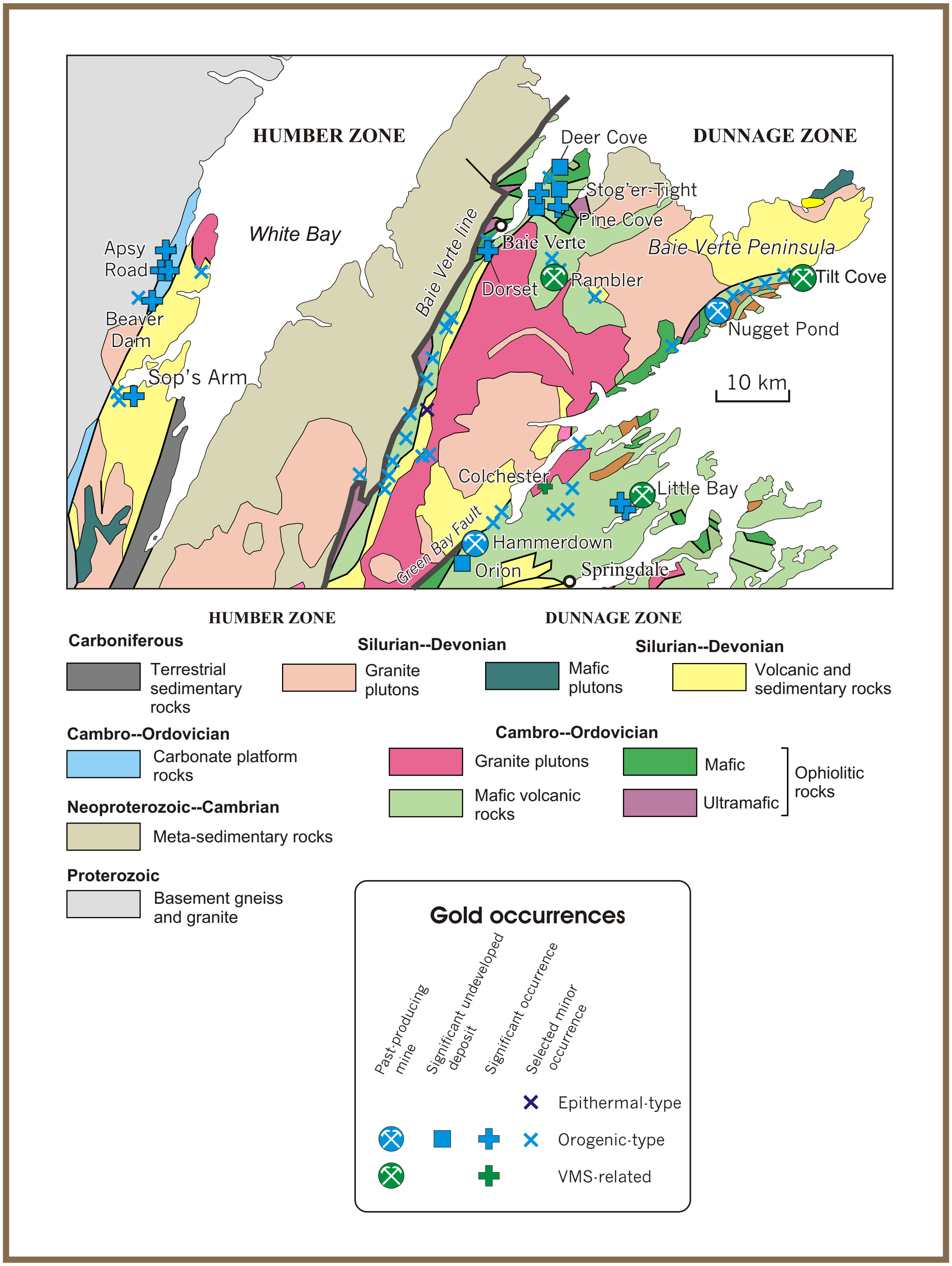


Figure 2.3: *Geological map of the White Bay–Baie Verte–Green Bay area, showing the locations of various types of gold deposit referenced and discussed in the text. From Wardle (in press).*

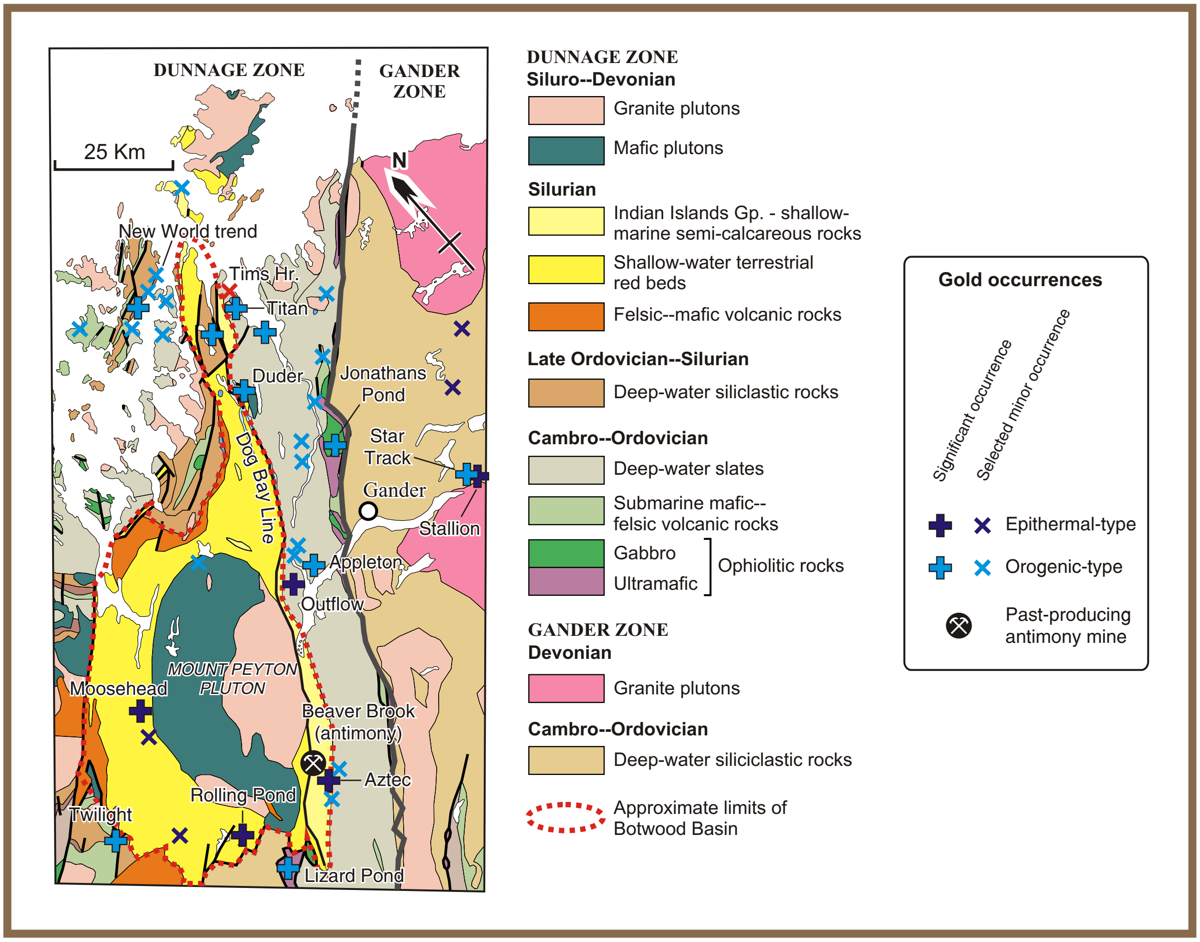
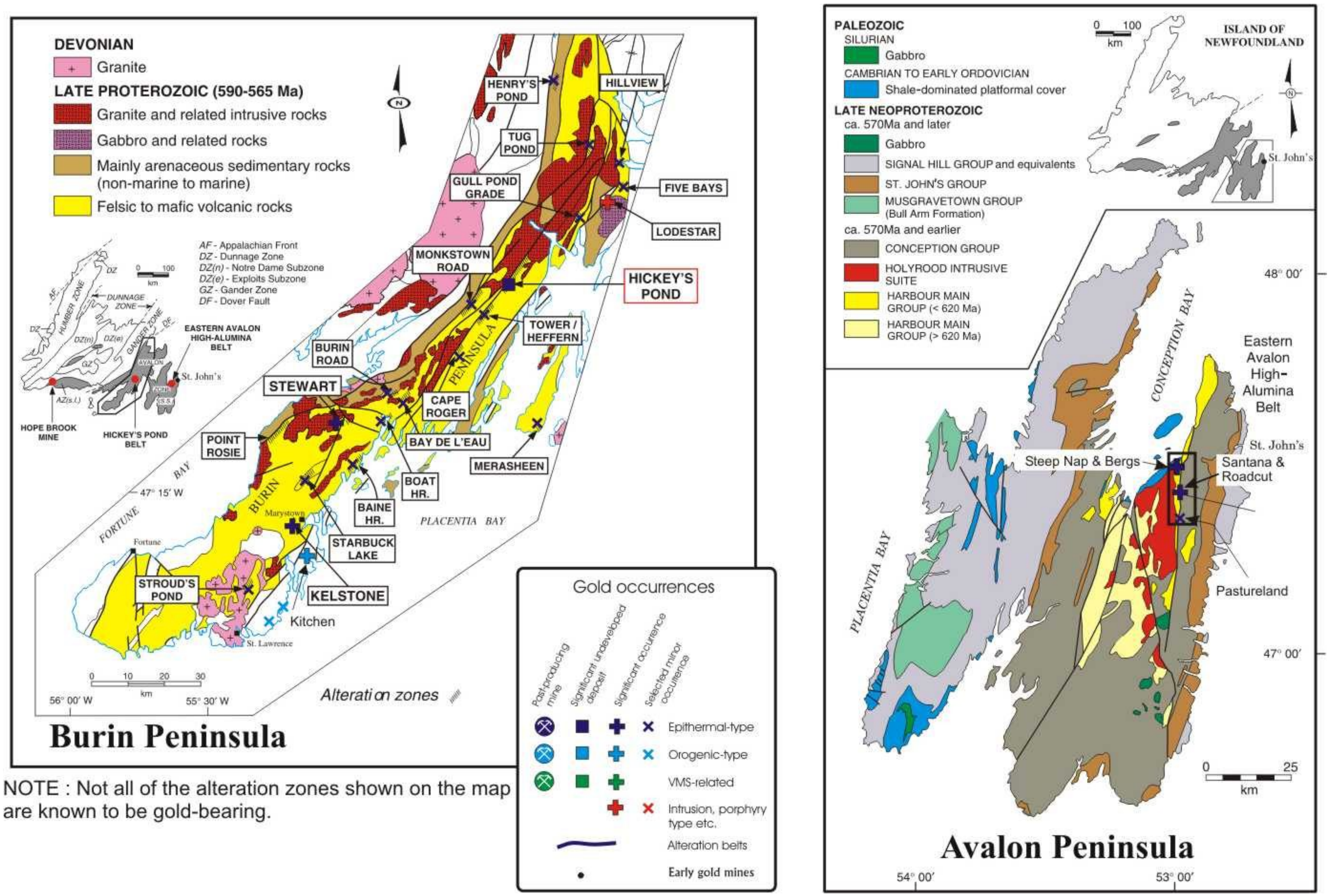


Figure 2.4: *Geological map of the eastern Dunnage Zone and adjacent Gander Zone in the Grand Falls Gander fogo area, showing the locations of various types of gold deposit referenced and discussed in the text. From Wardle (*in press*).*

northeastern Avalon Peninsula (Figures 2.1 and 2.5). The Burin Peninsula mineralization is of high-sulphidation type and consists of a series of hydrothermal, advanced argillic to silicic alteration belts that extend the length of the peninsula, and which are generally located in subaerial felsic volcanic rocks. Alteration mineral assemblages include pyrophyllite, alunite, specularite, quartz, sericite and locally lazulite. The best examples are the Hickey's Pond and Monkstown Road prospects, which lie within two parallel mineralization belts (Figures 2.1 and 2.5). Not all of the alteration zones are demonstrably auriferous, but many are unexplored.

Mineralization in the northeastern Avalon Peninsula (O'Brien *et al.*, 1998; Mills *et al.*, 1999; O'Brien *et al.*, 2005) is contained mostly within the Eastern Avalon High-Alumina Belt (Figures 2.1 and 2.5), which extends along the faulted, eastern side of an uplift cored by the ~620 Ma Holyrood Granite. This is the largest hydrothermal alteration zone in the Province and is located within subaerial felsic volcanic rocks. The alteration zone contains examples of both low- and high-sulphidation epithermal mineralization. Advanced argillic alteration has produced extensive pyrophyllite alteration in the volcanic rocks, from which massive pyrophyllite has been mined for many years at the Manuels Mine. Low-sulphidation mineralization (e.g., Steep Nap and Bergs prospects) is characterized by zones of hydrothermally brecciated auriferous quartz veins having colloform to crustiform texture and typically con-



NOTE : Not all of the alteration zones shown on the map are known to be gold-bearing.

Figure 2.5. *Locations of gold occurrences on the Burin and Avalon peninsulas of the Avalon Zone in Newfoundland. Note that not all of the epithermal-style alteration zones on the Burin Peninsula are confirmed as auriferous. Modified after O'Brien* et al. *(1998, 1999, 2001, 2005).*

taining quartz–adularia–hematite assemblages. The Bergs prospect has recently given a grab sample grade of 54.3 g/t. Gold is also found in hydrothermal breccias such as the Roadcut prospect. These are typically developed within zones of intense silica flooding, have a pyritiferous matrix and contain up to 210 g/t silver in grab samples. The northeastern Avalon Zone mineralization is believed to be somewhat older (635-620 Ma) than mineralization on the Burin Peninsula and at Hope Brook on the south coast (590-560 Ma). There thus appear to be at least two important periods of late Neoproterozoic volcanism and associated gold mineralization.

Epithermal gold mineralization in central Newfoundland is located mainly around the Botwood basin, an area of Silurian shallow-marine to fluviatile sedimentary rocks disposed around the Mount Peyton granite pluton (Figure 2.4). The basin more likely reflects structural preservation of the Silurian rocks around an uplift, and is probably not a true depocentre. Gold mineralization is described by Evans (1996, 2001a) and by Squires (2005). Significant epithermal occurrences include the Aztec, Rolling Pond, Outflow and Moosehead prospects and several smaller showings. These are of intermediate to low-sulphidation type and associated with silicification, quartz veining and brecciation. Rolling Pond preserves silica sinter indicating formation at, or near, paleo-surface levels. The Moosehead prospect has so far given the best grades of up to 227 g/t over 0.44 m, and is being actively explored. Southeast of Moosehead, at Paradise Lake, spectacular “geyserite” eggs and quartz-breccia float is reported, indicating a fossil geothermal system.

Other epithermal gold occurrences (Figure 2.1) are found in the central Dunnage Zone, e.g., Bobby’s Pond, which is a high-sulphidation type and associated with native sulphur and orpiment, and in the Gander Zone, where the best examples are the Stallion prospects near Benton (Figure 2.4), which consist of low-sulphidation quartz–chalcedony breccia veins having spectacular crustiform and botryoidal textures.

MESOTHERMAL ENVIRONMENTS (“OROGENIC GOLD”)

This broad class includes a wide variety of deposits that share common attributes of being vein-hosted, and associated with major faults or shear zones. These deposits have late orogenic timing with respect to deformation of their host rocks (Figure 2.2). Gold mineralization of this type is extensive throughout the Dunnage Zone of central Newfoundland, and is also known in adjacent parts of the Humber and Gander zones (Figure 2.1). Relatively reactive rock types, such as mafic intrusions, iron-rich or graphitic sedimentary rocks, and carbonate rocks, seem to be important as hosts for mineralization, and these compositional factors may be important controls. Extensive carbonate alteration, presence of CO_2-rich fluid inclusions, and the generally late orogenic timing have been used to suggest formation from metamorphic fluids, and the “orogenic gold” models (e.g., Groves *et al.*, 1999; Goldfarb *et al.*, 2000) are probably applicable to most examples. However, the genesis is not always clear and some occurrences may be intrusion-related rather than orogenic. Some occurrences, particularly in the eastern Dunnage Zone, are also associated with textures that suggest a formation-level transitional to epithermal styles, and there is spatially associated epithermal-type mineralization. The characteristics of these deposits are reviewed by Dubé and Lauziere (1997), Evans (1999, 2001a, 2004), Kerr (2004, 2005), Sangster and Pollard (2001), Saunders (1990) and Tuach *et al.* (1988).

Humber Zone

Within the Humber Zone, the only significant Au occurrences are in western White Bay (Figure 2.3), where a sliver of Cambro-Ordovician platformal cover rocks has been thrust against the Precambrian basement granites and gneisses of the

Humber Zone. Both basement and cover rocks are intruded by a Silurian plutono-volcanic complex that may have provided the thermal energy for hydrothermal alteration systems located along the basement-cover fault contact. There are three main areas of gold mineralization: the Beaver Dam, Road and Apsy zones (collectively known as the Rattling Brook prospect). Most of the mineralization is low grade (less than 4.4 g/t Au) and located within Precambrian granites, where it is associated with stockwork-style quartz veining and disseminated pyrite and arsenopyrite. Similar mineralization has also locally affected the overlying Cambro-Ordovician rocks, where gold is found mostly in the basal quartzites but reaches peak values of up to 11 g/t in the basal, iron-rich part of the overlying semi-calcareous Forteau Formation. Gold mineralization is present, perhaps intermittently, along a 4-km strike length and suggests an attractive stratigraphic target. It has previously been viewed as broadly mesothermal in character (e.g., Tuach, 1987; Saunders, 1990), but recent exploration has been based upon revised models suggesting Carlin-type affinities. The geochemistry of the mineralization (Kerr, 2005) has some affinities with the distinctive patterns reported from Carlin-type deposits in the Great Basin of the USA, and from so-called non-carbonate-hosted disseminated/stockwork deposits (Poulsen *et al.*, 2000).

Gold mineralization in quartz–carbonate veins, associated with base-metal sulphides, is also found within the Silurian sedimentary and felsic volcanic rocks of the Sops Arm area where it formed the basis for one of Newfoundland's earliest attempts at gold production at the Browning Mine (Sop's Arm, Figures 2.1 and 2.3). This mineralization has not been studied in detail, but it is of more typical mesothermal vein-hosted character than the mineralization at Rattling Brook.

Western Dunnage Zone (Notre Dame Subzone)

The western part of the Dunnage Zone includes the Baie Verte and Springdale peninsulas, and it has been the most prolific area, to date, for orogenic gold mineralization of mesothermal type (Figure 2.3). The Baie Verte Peninsula (Evans, 2004) hosts several significant undeveloped Au deposits (Deer Cove, Stog'er Tight and Pine Cove; Table 2.1; Figure 2.3), most of which are hosted by quartz–carbonate–pyrite vein systems within ophiolitic mafic rocks, spatially associated with major structural breaks including thrust faults. These mafic-rock-hosted deposits are typically associated with intense carbonate-pyrite wall-rock alteration and have been compared to the Californian "Mother Lode" deposits on the basis of regional geology and the proximity of ultramafic rocks representing possible Au sources. The Pine Cove deposit is currently being evaluated for possible production in late 2005 or early 2006. Mineralization is also locally hosted by sedimentary rocks of the eastern Baie Verte Peninsula. The most notable example is the Nugget Pond deposit (Figure 2.3), where gold is hosted within a thin clastic unit overlying pillow lavas of the Betts Cove ophiolite sequence (Pollard and Sangster, 2001). Nugget Pond was mined from 1997 to 2001, and contained some 490,000 tonnes at grades of ~12 g/t Au. As its name suggests, the deposit was renowned for its spectacular native gold, found in high-grade pockets. Mineralization occurs as a stratabound zone of disseminated pyrite–stilpnomelane alteration in association with veins, irregular clots and pegmatitic zones of quartz–albite–calcite ± pyrite material. Gold deposition appears to have been promoted by sulphidation of magnetite-rich zones within the basal sedimentary sequence, with the access of mineralizing hydrothermal fluids being controlled by a crosscutting fault. Another example of this process is the Goldenville deposit (Figure 2.1), which was mined around 1903. At this location, vein-style mineralization is found within a banded magnetite iron formation. Similar rocks to those of the Baie Verte Peninsula, including ophiolites, are also found in the Grand Lake area, where Glover Island hosts numerous vein-hosted prospects, including the small Kettle Pond deposit.

The Springdale Peninsula contains the Hammerdown Mine and the Orion deposit. The Hammerdown deposit (including the nearby Muddy Shag and Rumbullion zones), consists of sulphide-rich, quartz and quartz–carbonate veins hosted by Cambro-Ordovician volcanic rocks, and is one of several occurrences that are spatially associated with the Green Bay fault, a major regional shear zone (Figure 2.3). Hammerdown was another small but high-grade deposit, containing some 460,000 tonnes at ~17 g/t Au; it is described by Andrews (1990) and Ritcey *et al.* (1995).

The Cape Ray fault zone at the southwestern extremity of the Dunnage Zone (Figure 2.1) is host to three deposits discovered during the 1980s, namely the 04, 41 and 51 deposits (grouped as Cape Ray in Table 2.1). The fault is a major mylonite zone developed during continental collision in the Late Silurian Salinic Orogeny. The deposits were the subject of feasibility studies in the mid 1980s and in 1990, and are once again the subject of an advanced exploration program aimed at increasing the total resource. Gold mineralization is predominantly within complex multiphase auriferous quartz–base-metal veins located within Ordovician to Silurian graphitic schists of the Windsor Point Group. Gold was introduced synchronously with shearing along this major boundary (Dubé and Lauziere, 1997). Other related prospects along the fault zone are hosted by the Windowglass Hill granite and iron-rich metasedimentary rocks of the Windsor Point Group. The Windowglass Hill deposit appears to be associated with tensional quartz veins developed in this relatively brittle host rock type adjacent to the fault zone (Basha *et al.*, 2005).

Eastern Dunnage Zone (Exploits Subzone)

The granitic and volcanic rocks of this region host several important vein-hosted gold deposits (Evans, 1999, 2001). The most prominent examples (Figure 2.1) are Midas Pond (auriferous quartz–pyrite veins in heavily altered felsic volcanic rocks) and Valentine Lake (quartz–pyrite–tourmaline veins in a Neoproterozoic granite). The latter has recently given an inferred resource estimate of 1.3 million tonnes at 10.5 g/t. The thick Ordovician turbidite sequences that overlie the volcanic sequences also locally host interesting gold mineralization. An important recent discovery in a previously unexplored area is the Jaclyn vein at the Golden Promise project, which consists of a 375-m-long quartz-vein array located within folded greywackes and shales. This has given encouraging drill results of up to 17.7 g/t over 2.3 m, and remains open at depth; it also exhibits a consistent grade distribution (Copeland, 2004, 2005; Squires, 2005). The style of mineralization at Golden Promise is similar to that reported from other well-known turbidite-hosted gold provinces such as the Meguma Zone of Nova Scotia and the Bendigo-Ballarat area in Australia (Copeland, 2004). Other sedimentary-rock-hosted auriferous quartz veins in the eastern Dunnage Zone are True Grit, Twilight and the Appleton linear prospects (Knob, Bullet and Dome). These showings are spatially associated with northeast-trending topographic linears probably related to faults (Evans, 1996, 2001).

On the southeastern margin of the Dunnage Zone (Figure 2.1), felsic volcanic rocks near Bay d'Espoir host several auriferous quartz-vein occurrences (e.g., Little River and Wolf Pond), in which gold is generally associated with stibnite and arsenopyrite. Other gold prospects are associated with the northeastern part of the Dunnage Zone where it overthrusts the Gander Zone (Figure 2.4). This contact is decorated by a string of dismembered ophiolitic rocks (the Gander River ultramafic belt, or GRUB line) and contains several gold prospects (e.g., Jonathans Pond) in a setting similar to that of the Baie Verte Peninsula (Evans, 1996). Several nearby significant prospects are also hosted by metagabbroic rocks, notably the Duder Lake and Titan prospects. These are associated with strong silica and iron-carbonate alteration and are located close to the Dog Bay Line, a major late-orogenic fault. Also, a number of vein-hosted gold occurrences have been recently discovered along a series of northeast-trending linear features in mid to Upper Ordovician sedimentary sequences (including mélange and associated porphyry intrusions) of eastern Notre Dame Bay, e.g., the New World trend (Figure 2.4), where values up to 87 g/t over 0.8 m have been recorded in channel samples. Much of the exploration work in this area is recent, but summaries are provided by Squires (2005).

Gander and Avalon Zones

The Gander and Avalon zones have, to date, revealed relatively few orogenic-type mesothermal gold occurrences; however, recent exploration has discovered several new prospects in the metasedimentary rocks of the Gander Group (e.g., Star Track, Figure 2.5). The Avalon Zone contains some small occurrences of shear-zone-related mineralization (e.g., the Kitchen prospect) in a belt of ophiolitic rocks belonging to the Neoproterozoic Burin Group at the southern end of the Burin Peninsula (Figure 2.1). The setting and iron-carbonate alteration of these occurrences are also reminiscent of Mother Lode and Baie Verte mineralization styles (O’Driscoll *et al.*, 2001).

INTRUSION-ASSOCIATED ENVIRONMENTS

As used here, this classification includes all deposit types related to igneous intrusions, including porphyry and intrusion-related (*sensu stricto*) types (Figure 2.2). There are few examples of these in the Province, but there has been little or no systematic exploration for gold in the large areas dominated by plutonic rocks. The Grey River area, which is situated within a Siluro-Devonian batholith on the south coast of Newfoundland (Figure 2.1), is noted for its quartz-vein-hosted tungsten mineralization but also contains a zone of copper–molybdenum–gold mineralization. Although this was originally interpreted as a porphyry-style environment, it has been suggested that the co-existence of gold (up to 1.0 g/t) with antimony–bismuth–tungsten mineralization may indicate an intrusion-related environment similar to that of the Alaskan Pogo and Fort Knox deposits. The Wood Lake (Au–As–Cu) and Tims Harbour (Au–As–W–Cu) occurrences, on the western and eastern sides of the Dunnage Zone respectively, may represent additional examples of intrusion-related mineralization. Other examples are located within the Avalon Zone of eastern Newfoundland and include the Neoproterozoic Lodestar Au–As–Cu prospect (Hinchey *et al.*, 2000), and perhaps the Butlers Pond and Triangle Pond Au–Cu showings associated with the 620 Ma Holyrood Granite (Figure 2.1).

CARLIN-TYPE ENVIRONMENTS

The potential for Carlin-type mineralization, i.e., disseminated gold-pyrite mineralization forming stratabound or discordant replacements in semi-calcareous sequences, has recently received much attention in Newfoundland. The eastern Botwood basin contains a belt of Silurian semi-calcareous and siliciclastic rocks known as the Indian Islands Group (Figure 2.4), which has been reported to contain signatures of Carlin-type mineralization including decalcification, silicification and vuggy jasperoid development. However, most of the mineralization encountered to date has rather low grades, and other interpretations are equally valid (Squires, 2005).

Unusual disseminated to stockwork-style gold mineralization hosted by Precambrian granites and basal Cambro-Ordovician rocks of the western White Bay area (Figures 2.1 and 2.3) has also been interpreted in terms of Carlin-type environments, although it is summarized above with mesothermal orogenic gold environments. The gold-only character of this mineralization, coupled with its association with As, W, Te and Sb, is consistent with such models (Kerr, 2005), but more data are required, notably on the habitat of the gold.

TIMING OF GOLD MINERALIZATION IN NEWFOUNDLAND

Gold mineralizing systems in the Newfoundland Appalachians range in age from Late Neoproterozoic in the Avalon Zone to Silurian or Devonian. However, because most of the gold mineralization is epigenetic with respect to its host rocks, the exact timing of mineralization is not well constrained, and most estimates to date rely upon indirect methods, or involve subjective reasoning. Direct dating of gold mineralization, for example by using Re–Os geochronology on sulphide minerals such as pyrite and arsenopyrite, has not yet been attempted on a large scale.

Precambrian mineralization in the Avalon Zone is believed to record two metallogenic pulses at 635-620 Ma and 590-560 Ma (O'Brien *et al.*, 1998; see above). These correspond with regional magmatic episodes linked either to continental arc development and/or amalgamation of volcanic terranes during the Pan-African orogeny, which assembled the Avalon Zone and related peri-Gondwanan terranes. Mineralization has not been dated directly or precisely.

VMS-associated gold-rich sulphide deposits are essentially syngenetic with respect to their host rocks, and their ages in are thus known precisely. Some of the older examples (e.g., Duck Pond) are of Early Cambrian age (~513 Ma), whereas the youngest (e.g., Buchans) are Early to Middle Ordovician (~473 Ma). As discussed previously, the VMS deposits record various episodes of arc and back-arc basin development within the Ordovician Iapetus Ocean.

Mesothermal "orogenic" gold mineralization throughout the Dunnage Zone is inherently difficult to date due to its epigenetic character. The spatial distribution of mineralization implies a link to major fault systems, but these have a long history of activity, and at least some remained active as transcurrent faults into the Carboniferous. It is generally assumed that gold mineralization across the Dunnage Zone is of Silurian and younger age, and is thus broadly associated with the Salinic Orogeny, which is the dominant deformational and metamorphic event in the region. Felsic dykes that are cut by auriferous veins at the Hammerdown Mine have a U–Pb zircon age of ~437 Ma, but this provides only an upper limit (Ritcey *et al.*, 1995). Zircon interpreted to be of hydrothermal origin at the Stog'er tight deposit yielded an age of ~420 Ma (Ramezani, 1992). Amongst the Silurian volcanic and sedimentary sequences of Newfoundland, gold mineralization is less common, although the Sops Arm Group in the Humber Zone contains auriferous veins, and some mineralization has recently been reported from the eastern Dunnage Zone in rocks that may be as young as latest Silurian. Xenotime within a quartz–felspar–carbonate alteration assemblage at the Nugget Pond Mine has given a U–Pb age of ~374 Ma, indicating the likelihood of Devonian gold mineralization (Sangster and Pollard, 2001). Recent dating of mafic host rocks to gold mineralization in the eastern Dunnage Zone (McNicol, 2005) also indicates that some mineralization must be Devonian.

In summary, the exact number and timing of gold mineralizing events across much of Newfoundland remains poorly constrained, and there is a pressing need for direct dating of deposits. Re–Os work conducted in the Meguma Zone of Nova Scotia (Kontak *et al.*, 2004) has shown that superficially identical gold-bearing veins at two nearby deposits differ in age by almost 30 Ma.

EXPLORATION POTENTIAL

Gold mineralization in Newfoundland has been cyclic, as for most commodities, but it has been on an upswing since 2002, driven partly by rising metal prices, but also by the application of new deposit models at the grassroots level. The many recent discoveries made by basic prospecting, some in areas with little history of gold exploration, further underlines the grassroots potential. As a result, nearly all known gold deposits in the Province are undergoing renewed exploration and evaluation.

For gold-only deposits, orogenic gold mineralization seems to be the favoured target, mainly in the Dunnage Zone where the Pine Cove, Cape Ray and other deposits represent advanced exploration targets. Promising new grassroots targets, such as the Golden Promise (Jaclyn) area, Valentine Lake, New World trend and Titan prospects, are also being generated. Some of these are in the previously little-explored sedimentary rocks that overlie the volcanic arc sequences, indicating considerable potential for further discovery. The deposit model being considered for this type of mineralization is referred to as turbidite-hosted gold and its potential is underlined by the world-class district of southeast Australia.

Existing data suggest that the most prospective orogenic gold environments are those associated directly or indirectly with major faults or shear structures, particularly in structurally competent units where brittle fracturing may produce thick vein development, and where reactive host rocks are present. Good examples of prospective host rocks, together with relevant examples, are mafic intrusive or volcanic rocks (e.g., Pine Cove, Deer Cove, Stog'er Tight, Duder Lake and Titan), Fe-rich sediment or iron formation (e.g., Nugget Pond, Goldenville and Rattling Brook), graphitic sedimentary rocks (e.g., Cape Ray) and siliciclastic rocks (e.g., Appleton, Golden Promise (Jaclyn). Brittle, competent host rocks, such as the Windowglass Hill granite at Cape Ray, also provide important structural hosts regardless of chemical influences.

The epithermal-style environments have proven production potential and the high- and low-sulphidation environments of the Avalon and Dunnage zones will continue to represent attractive targets, both for medium-size deposits such as the Hope Brook Mine and for smaller high-grade "bonanza" deposits. Most epithermal-style gold mineralization identified to date is associated with well-preserved volcanic and sedimentary units; however, the Hope Brook deposit indicates that such mineralization can also be preserved in strongly deformed and highly metamorphosed rocks.

In addition to gold-only deposits, auriferous VMS deposits continue to provide attractive exploration targets. Prominent examples include the Colchester property, a copper-rich VMS deposit near Notre Dame Bay (Figure 2.3), the deep, down-plunge extensions of the Rambler camp deposits (Figure 2.3) and the Mary March prospect near Buchans (Figure 2.1), where Buchans-like polymetallic mineralization is present.

The potential for intrusion-related gold deposits and for large disseminated gold deposits in sedimentary host rocks (Carlin-type) still remains largely untested in Newfoundland. The extensive plutonic terranes of the Gander Zone and the south coast of the island have yet to receive systematic gold exploration. There are hints of sedimentary-rock-hosted gold mineralization in western Newfoundland, and elsewhere, but the platformal carbonate sequence of the west coast has never been explored, despite the presence of surficial gold anomalies. The geological anatomy of western Newfoundland, where allochthon boundary faults bring deep-water siliciclastic rocks over the carbonate platform, is very reminiscent of parts of the Carlin district in Nevada.

To close this section, the history of gold exploration in Newfoundland convincingly demonstrates that not only is gold "where you find it", but it seems to be where you look for it!

SECTION 3 : FIELD TRIP STOP DESCRIPTIONS

(Andrew Kerr, David W. Evans, Sean J. O'Brien, Gerald C. Squires)

INTRODUCTION

This section of the guide provides location information and descriptions of field-trip stops visited during this excursion. The level of description varies, depending upon the availability of information for individual occurrences. Note that in many cases, additional written information will be provided to participants from unpublished Geological Survey sources or from exploration companies who currently hold mineral rights in specific areas. Field trip stops in the Avalon Zone are summarized only briefly below, but are described in detail in a separate guide (O’Brien *et al.*, 2005). The field trip stops are subdivided as follows:

Day 1:	Neoproterozoic epithermal gold mineralization in the eastern Avalon Zone.
Day 2 (Morning):	Neoproterozoic intrusion-related gold mineralization in the western Avalon Zone.
Day 2 (Afternoon):	Mesothermal and epithermal gold mineralization in the Gander Zone.
Day 3:	Mesothermal and epithermal(?) gold mineralization in the Eastern Dunnage Zone between Gander and Twillingate.
Day 4:	Gold mineralization in the Eastern Dunnage Zone in the Glenwood and Gander River areas.
Day 5 (Morning):	Mesothermal gold mineralization in the eastern Dunnage Zone in the Badger area.
Day 5 (Afternoon):	VMS-related gold mineralization in the western Dunnage Zone, Green Bay area.
Day 6:	Gold mineralization in the Baie Verte Peninsula area.
Day 7:	Mesothermal and “Carlin-like” (?) gold mineralization in the Humber Zone.

DAY 1: NEOPROTEROZOIC EPITHERMAL GOLD MINERALIZATION IN THE EASTERN AVALON ZONE

Leaders : Sean O'Brien, Rubicon Minerals Staff

Geological Background

The Avalon Zone of Newfoundland is a late Precambrian terrane on the eastern side of the Appalachian Orogen (*see* Section 1). It is an areally extensive and metallogenically important volcano-plutonic terrane that hosts some of the largest metamorphosed, precious-metal-bearing epithermal systems in Canada. Compared to the Paleozoic rocks of central Newfoundland to be visited later in this excursion, it remains underexplored.

The geology of the Avalon Zone is not discussed in detail here. A separate guide (O'Brien *et al.*, 2005) provides a summary of regional and local geology, and also provides more detailed information on gold mineralization and related alteration. A brief summary of the field-trip stops is given below for the convenience of readers; complete details are provided by O'Brien *et al.* (2005).

Summary of Field Trip Stops

The field trip leaves St. John's via the Trans-Canada Highway (Route 1), to the intersection of Routes 1 and 2. From there, we follow Route 2 west to Manuels, and turn southwest (left) at Manuels Bridge onto Route 60 (Conception Bay Highway). Geologically, the route to the first stop proceeds downward through much of the late Neoproterozoic stratigraphic section of the eastern Avalon Peninsula. The route starts in the deltaic sandstones and shales of the St. John's Group (which underlie much of the city of St. John's), proceeds downward through the Mistaken Point Formation and other marine siliciclastic sedimentary rocks of the Conception Group, across the Topsail Fault system, onto the eastern edge of the Holyrood Horst and the volcano-plutonic core of the Avalon Peninsula. The first stop is on the south side of Route 60, at Manuels River.

The itinerary includes field stops that will focus primarily on various styles of hydrothermal alteration and related gold, silver and base metal mineralization within late Neoproterozoic volcanic and plutonic rocks of the Avalonian Belt of the eastern Appalachians. All but the final stop are located in the *Eastern Avalon High-Alumina Belt*, an extensive area of hydrothermal alteration, greater than 15 km long and up to 1 km wide, located along the eastern flank of the Holyrood Horst. The trip begins at the northern end of the Eastern Avalon High-Alumina Belt, at the contact between hydrothermally altered volcanic and plutonic rocks (historically included within the Harbour Main Group and the Holyrood Intrusive Suite, respectively) and unaltered, shale-rich Cambrian platformal cover (Stops 1.1 and 1.2). The trip then proceeds southward along the alteration belt, to examine exposure of low-sulphidation style gold-bearing quartz–adularia–hematite veins and related breccias and host rocks at the Steep Nap prospect (Stops 1.3 and 1.4). The trip will then proceed farther south, stopping in the advanced argillic alteration system and the overlying Neoproterozoic sediments in and around the Oval Pit pyrophyllite mine (Stop 1.5), in post-alteration, high-strain zones within the advanced argillic zone at the Mine Hill Quarry (Stop 1.6) and in nearby silicic altered and auriferous breccias of the Mine By-Pass prospect (Stop 1.7), and low-sulphidation style veins within 1 km of the high-sulphidation system (Stop 1.8). At that time we will examine core from other mineralized vein systems in this belt that we could not visit on this trip. Our final stop in the Eastern Avalon High-Alumina

Belt is located on and near Route 1, near the intersection with Route 61 (Foxtrap Access Road), where the advanced-argillic-altered volcanic rocks and related gold-bearing (up to 11.2 g/t) hydrothermal breccias of the Roadcut gold prospect are well exposed (Stop 1.9). From there we walk to nearby trenches that expose the host volcanic rocks of the Santana Au–Ag prospect (Stop 1.10).

If time permits, the trip will then head farther south along a secondary gravel road for about 2 km, stopping in Zn–Pb–Cu–Ag–Au mineralization at the Pastureland Road prospect (Stop 1.11), near the Topsail Fault. This possible VMS-style mineralization is located in a marine mafic volcano-sedimentary unit that overlies the subaerial successions that are host to the epithermal alteration viewed earlier in the day.

DAY 2: (Morning): NEOPROTEROZOIC INTRUSION-RELATED GOLD MINERALIZATION IN THE WESTERN AVALON ZONE

Leaders : Sean O'Brien and others

Summary

As discussed in Section 2 of this guide, gold mineralization and related epithermal-style alteration is widespread in the Burin Peninsula area of the western Avalon Zone, but most of these occurrences are not easy to visit on a field trip of this nature. However, there is interesting intrusion-related gold mineralization near Goobies. Details of the geology of this area are provided by Hinchey *et al.* (2000) and O'Brien *et al.* (2005). Stop 2.1 will examine high-grade gold mineralization (with copper, arsenic and zinc) in late Neoproterozoic magmatic-hydrothermal breccias at the Lodestar prospect, on the Northern Burin Peninsula. A complete description of this mineralization is provided by O'Brien *et al.* (2005). Stop 2.2, located just west of Glovertown on the Trans-Canada Highway, consists of amphibolite-facies migmatites and granitoid rocks of the Gander Zone, adjacent to the Gander–Avalon boundary. These contrast strongly with the relatively well-preserved sedimentary and volcanic rocks of the Avalon Zone.

DAY 2: (Afternoon): MESOTHERMAL AND EPITHERMAL GOLD MINERALIZATION IN THE GANDER ZONE

Leaders : Gerry Squires, Rubicon Minerals Staff

Geological Background

The general geology of the Gander Zone is summarized in Part 1 of this guide. This region of Newfoundland contains relatively few gold occurrences. Gold mineralization in the Wing Pond area (Figure 3.1) was discovered in the early 1980s during Geological Survey mapping in the area. This has received some exploration, but has never been drilled. More recently, gold mineralization hosted by quartz veins was discovered in several areas close to the former route of the Newfoundland railway in the area east of Benton. This is currently under exploration by Rubicon Minerals.

Gold mineralization in the northeast part of the Gander Zone is hosted by metasedimentary rocks of the Gander Group, which consists of interbedded psammite, semipelite and pelite, and represents a metamorphosed turbidite sequence. It is divided into the Jonathan's Pond and Indian Bay Big Pond Formations. The rocks of the Gander Group have undergone polyphase deformation and metamorphism to greenschist and amphibolite facies. These sedimentary rocks are cut by several granitoid intrusions, the largest of which are the Deadman's Bay granite, the Middle Brook granite and the Gander Lake granite. These are all considered to be of Devonian age, although their ages are constrained by Rb–Sr, K–Ar and Ar–Ar methods; there are no published U–Pb ages from these plutons. The Gander Lake granite lies very close to the Benton area gold prospects (Figure 3.1).

Startrack Prospect: General Information

The Startrack prospect is located adjacent to the former course of the Newfoundland railway approximately 5 km east of the village of Benton, which is signposted from the Trans-Canada highway just east of Gander. The former railbed serves as a road leading east from Benton; it is narrow, but contains widened areas suitable as passing places.

The prospect consists of parallel quartz veins that intrude pelitic to psammitic metasedimentary rocks of the Gander Group. Detailed information remains confidential, and the only geological summary is by Squires (2005). The area is the subject of a Ph.D. thesis study by Chris Buchanan (Memorial University).

There are several generation of quartz veins that have variable relationships to structural features, but the veins with the highest Au values typically follow small northwest-dipping thrusts that are axial planar to F_3 folds (Rubicon Minerals, in Squires, 2005). The veins have returned assays of up to 20.7 g/t Au over 0.6 m in channel samples, and up to 256 g/t Au in grab samples. Gold appears to be directly associated with arsenopyrite, and is associated with sericitic and (locally) iron carbonate wall-rock alteration.

Stop 2.3
Startrack Prospect, Exploration Trench 2

This trench is located slightly to the north of the old railway bed. The host rocks are psammitic metasediments of the Gander Group (Jonathon's Pond Formation), and the outcrop contains complex folding. The largest quartz veins appear to be relatively early in the sequence. The most interesting gold values come from smaller quartz veins, that are more clearly discordant with the earlier structural features.

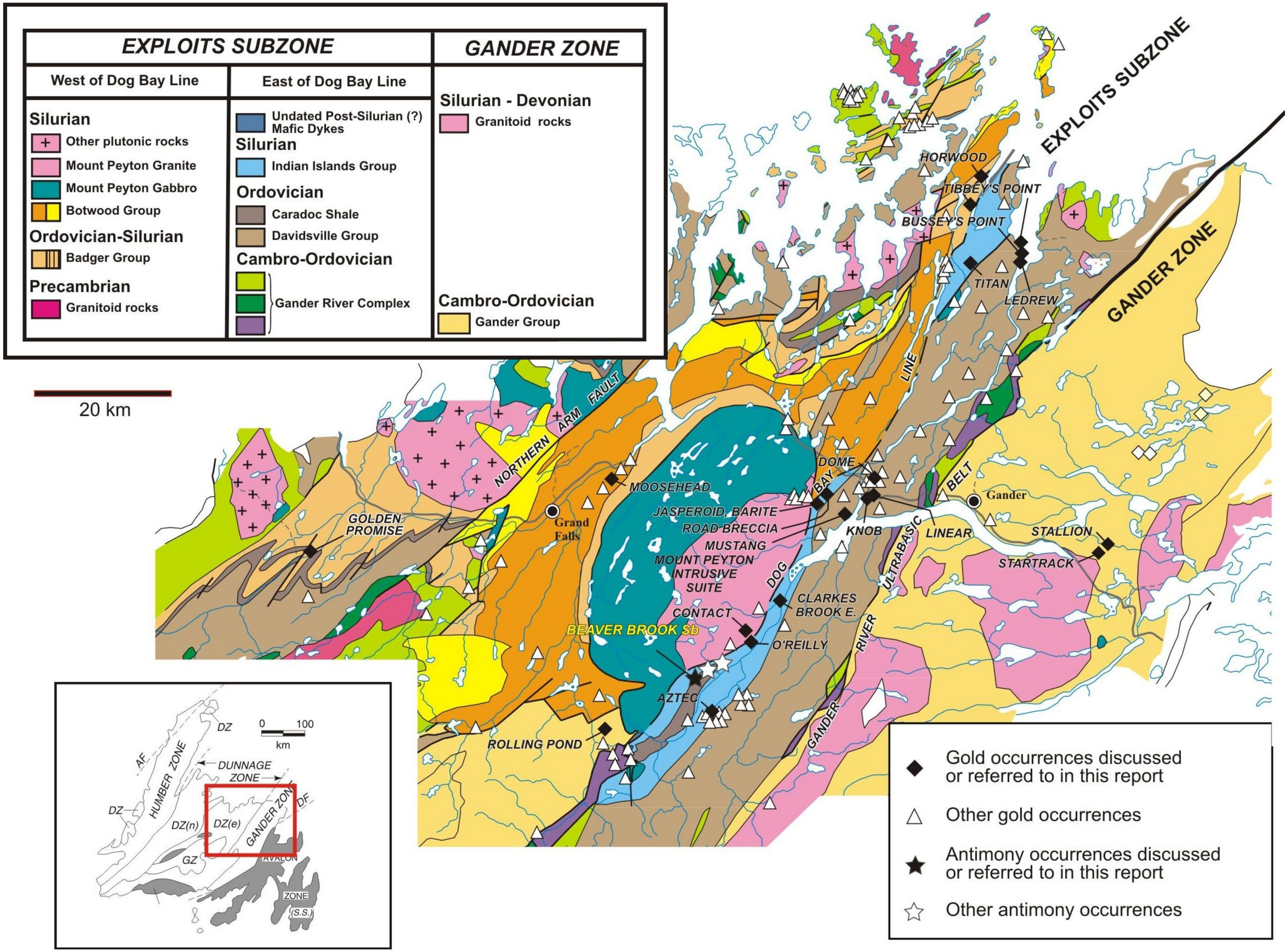


Figure 3.1. *Regional geology and principal gold occurrences in the eastern part of the Dunnage Zone and adjacent Gander Zone. Modified after Squires (2005).*

Stop 2.4
Folding in Gander Group Host Rocks

This outcrop is located about 1 km southeast of the previous stop, at the intersection between the old railway bed and a small woods road leading to the north. It contains spectacular folding, that can be resolved into three phases of deformation.

Stallion Prospect: General Information

The Stallion prospect is located about 1 km southeast of the Startrack prospect. It consists of a series of quartz veins that cut peltic to psammitic metasedimentary rocks of the Gander Group (mostly Jonathon’s Pond Formation). The host rocks also include cordierite schist, calcaerous semipelite, graphitic pelite and metachert. The eastern of the two main trenches exposes a unit of interbedded semipelite and limestone, which is correlated with the Indian Bay Big Pond Formation. Detailed information remains confidential, and the only geological summary is by Squires (2005).

The Stallion prospect contrasts markedly with the Startrack prospect. The quartz veins are distinguished by multiple generations of chalcedonic silica veining and hydrothermal brecciation. Locally, the veins display spectacular cockade texture, with cavities retained between fragments. The features of the veins suggest that they are of epithermal (low-sulphidation) type, in contrast to the mesothermal-style veins of the Startrack prospect. Locally, the veins contain minor green fluorite and minor stibnite. Gold grades range up to 3 g/t Au over 0.6 m in channel samples (Rubicon Minerals, *in* Squires, 2005).

Stop 2.5
Stallion Prospect, Western Trench

This large trench is located less than 300 m along the woods road that joins the old railway bed at the previous stop. It exposes the main series of auriferous quartz veins, and shows spectacular textures suggestive of an epithermal origin.

Stop 2.6
Stallion Prospect, Eastern Trench

This large exploration trench is located about 200 m farther east along the woods road. It exposes cordierite-bearing schists of the Gander Group, and a relatively high-grade quartz vein that contained up to 3 g/t Au (Rubicon Minerals, in Squires, 2005). A wide range of epithermal textures is developed, as at the previous stop, and this include rounded, egg-like masses of chalcedonic silica. Fluorite and stibnite are present locally.

Stop 2.7
Stallion Prospect, Northern Trench

This is another large exploration trench located almost 700 m north of the previous stop and best accessed by walking along the road, which is overgrown. It exhibits features similar to the other stops and will only be visited if time permits. Fluorite is relatively abundant in the veins at this locality.

DAY 3: MESOTHERMAL AND EPITHERMAL (?) GOLD MINERALIZATION IN THE EASTERN DUNNAGE ZONE BETWEEN GANDER AND TWILLINGATE

Leaders : Gerry Squires, David Evan, Crosshair Exploration Staff

Geological Background

The area to be visited during Day 3 lies north and northwest of Gander between Gander Bay and the Bay of Exploits (part of Notre Dame Bay). This area forms the easternmost edge of the Eastern Dunnage Zone (Exploits Subzone), described in general terms in the first section of this report. The area around the course of the Gander River (Figure 3.1) was explored in the 1980s, resulting in the discovery of several gold prospects, notably at Jonathon's Pond, Big Pond, and the Duder Lake area (Figure 3.1). The gold mineralization at these and other smaller occurrences is described by Evans (1996). Most are no longer easily accessible, and they will not be visited on this excursion. More recent exploration work by several junior companies led to the discovery of several new gold prospects. Public-domain information on these is presently very limited, but is summarized by Squires (2005).

This area of the Exploits Subzone lies east of an important structural lineament termed the Dog Bay Line, which is thought to represent a major Silurian tectonic boundary (Williams *et al.*, 1993). The area is dominated by rocks of the Davidsville Group, which consist of siliciclastic rocks (sandstones, siltstones and shales) of Cambrian and Ordovician age. The Davidsville Group youngs westward into rocks of progressively deeper water affinity. The siliciclastic rocks of the Davidsville Group are in part of volcanogenic origin. The Davidsville Group locally retains an unconformable relationship with the structurally complex volcanic, plutonic, and ophiolitic rocks of the Gander River Complex (O'Neill and Blackwood, 1989), which marks the boundary between the Exploits Subzone and the adjacent Gander Zone. This is also known as the Gander River Ultramafic Belt (GRUB line; *see* Section 1). Where the ultramafic rocks are absent, the Davidsville Group is in tectonic contact with the metasedimentary rocks of the Gander Group, visited on Day 2 (Williams, 2001).

The upper part of the Davidville Group consists of black shale and chert of Caradocian (Middle Ordovician) age. These rocks are, in turn, overlain by siltstone, shale, red sandstone and limestone of the Indian Islands Group, of Silurian age. The basal contact of the Indian Islands Group with the Davidsville Group has never been observed, but is generally considered to be conformable where not structurally modified (Williams *et al.*, 1993). The Indian Islands Group is relatively well exposed in coastal areas, and also has been recognized in inland areas southeast of the Mount Peyton Intrusion. The gap between these two areas indicated in Figure 3.1 may be artificial, as some of the rocks in this area (the Ten Mile Lake Formation of Currie, 1997) likely represent Indian Islands Group rather than Botwood Group. The contacts between the Indian Islands Group and surrounding units in the south appear to be mostly fault-defined, and it includes lenticular fault-bounded zones of sheared Caradocian black shales, hinting at unresolved structural complexities. These (and many other issues) are beyond the scope of this guide.

Stop 3.1
Bussey's Point Showing

From Gander, drive north to Gander Bay, and turn west across the causeway into Clarkes Head, and then north to Wings Point. At the south end of the village, a side road forks to the right. The showing is located at the end of the road, and is best visited at low tide. It consists of thick sheeted quartz veins that are hosted by the Davidsville Group greywackes and shales. There is very little geological information on this locality, but a summary is provided by Squires (2005).

The host rocks are folded greywackes and shales of the Davidsville Group, which strike east-northeast, but dip at variable attitudes due to folding. The sedimentary rocks are cut by grey, light-weathering granitic dykes that may be offshoots from the Fredericton pluton, located a few kilometres northeast of here. A strong cleavage in the outcrop, dipping moderately to steeply south, is probably axial planar to the folds. The quartz veins are oriented approximately parallel to this cleavage. The wall rock to the veins is altered, and locally contains up to 10 percent disseminated arsenopyrite and pyrite. To date, this showing has returned only anomalous Au values <1 g/t Au. However, it may be part of a far more extensive vein system that may extend for up to 2 km to the area of the Ledrew showing (a subsequent stop).

Stop 3.2
Tibbey's Point Showing

From Bussey’s Point, return to the main road in Wing’s Point, and drive north for about 2.5 km, and turn right on a side road. Continue along this road for almost 2 km, to a point almost at the end. There is little public-domain information, but it is summarized by Squires (2005). It consists of a thin (<30 cm-wide) steeply south-dipping quartz vein, which is locally deformed and appears to trend parallel to the axial planar cleavage in the folded shale and sandstone of the Carmanville Mélange, which is here grouped with the Davidsville Group (Figure 3.1). The quartz vein contains polymetallic mineralization, characterized by pyrite, chalcopyrite, arsenopyrite and boulangerite (G. MacVeigh, quoted by Squires, 2005). The wall rock contains pyrite. One grab sample from the vein gave an assay of 47.4 g/t Au, and some previous drilling at this location intersected 10 g/t Au over 1.15 m (Squires, 2005).

Stop 3.3
Ledrew Showing

From Tibbey’s Point, return to the main road, and drive south again into Wing’s Point. The Wing’s Point forest access road branches to the west just south of the Ball Park in the centre of the community. Continue along this road for about 1 km, to a series of gravel pits which are (unfortunately) used as an unofficial dump site. This showing is located in a pit south of the woods road. It consists of low-grade quartz veins hosted by greywacke and shale of the Davidsville Group. A brief description is provided by Squires (2005). The area around the showing hosts widespread arsenopyrite patches, notably in Davidsville Group shales, in some cases hundreds of metres from the quartz veins. The Ledrew showing may be a direct along-strike extension of the Bussey's Point showing (*see* above) suggesting the presence of an extensive vein system in this area. Grab samples at the Ledrew showing have yielded up to 11.6 g/t Au, and channel samples have given up to 1.1 g/t Au over 1 m (Squires, 2005).

Stop 3.4
Titan Showing

From the Ledrew showing, continue west along the woods road for about 6 km. It gets progressively rougher and may be unsuitable for vehicles lacking four-wheel drive. The Titan showing (Figure 3.1) is a recent discovery, currently under exploration by Crosshair Exploration, and much information remains confidential. A short summary is given by Squires (2005).

The showing consists of several quartz vein systems that are hosted by a gabbroic dyke that sits within laminated and crossbedded sandstones considered to be part of the Indian Islands Group, rather than the Davidsville Group (Currie and

Williams, 1995). Therefore, the host rocks at this locality must be Silurian or younger based upon this field evidence, although contacts between dykes and country rocks are hard to find. The quartz veins are associated with strong iron-carbonate alteration, which creates an orange-brown colour through much of the exposed area. The quartz veining appears to be preferentially developed in the gabbroic dykes rather than the more ductile country rocks. Free gold is present in the veins, although it can be difficult to find! The best results from drilling at this location were 10.2 g/t Au over 3.35 m and grab samples contained up to 40 g/t Au. (Crosshair Exploration, press release, 2004).

The Titan showing has recently given U–Pb geochronological data that are of interest in the context of the timing of gold mineralization. A SHRIMP study of a gabbro cut by auriferous veins (McNicoll, 2005) yielded a complex zircon population with ages ranging from 586 to 381 Ma. The older ages are believed to be inherited zircons, likely derived from sedimentary country rocks. The youngest population, which defines an age of 381 ± 5 Ma, is interpreted as the crystallization age of the gabbro. The results indicate that mesothermal gold mineralization at this locality is younger than 381 Ma, i.e., it is of Devonian age (McNicoll, 2005).

Stop 3.5
Fanacy Fossil Locality

From the Titan showing, return to the main road in Wing’s Point, and head northward, through the villages of Victoria Cove and Rodgers Cove. Just less than 3 km beyond the road junction in Rodgers Cove, a dirt road branches off to the right (north). The outcrop is located less than 200 m along this road.

There is no mineralization at this locality, which exposes a carbonate unit within the Silurian Indian Islands Group. However, it is an interesting fossil locality that contains solitary corals, chain corals, bryozoa and gastropods.

Stop 3.6
Horwood Quartz Vein Breccia

Continue northward on the main road for almost 6 km, then turn right at the signpost for Horwood. Continue along this side road for almost 3 km until it leaves the shoreline. Park near here and walk around the small headland, preferably at low tide. At high tide, walk north along the road and cut directly across to the shore. This interesting locality in the village of Horwood, on the east shore of Dog Bay, consists of spectacular quartz vein breccias, developed in Ordovician (?) slates and strongly sheared rocks that define the Dog Bay Line in this area. It is described by Squires (2005).

The quartz veins display multiple phases of chalcedonic and crustiform material, disrupted by several phases of brecciation, suggesting strongly that this developed in an epithermal environment. The veining clearly postdates the fabric development in the host rocks and (assuming that the latter is of Silurian age) must be of post-Silurian age. There is presently no information on the Au concentrations of these veins, but they attest to the possibility of epithermal-style gold mineralization in addition to the mesothermal environments recognized in this area.

Stop 3.7
The Dunnage Mélange

This location is a roadside exposure on Route 340, on New World Island (Figure 3.1). From the previous stop, return to the main road between Gander Bay and Boyd’s Cove, and drive west to Boyd’s Cove, and then turn north on Route 340 toward Twillingate, crossing causeways and bridges that link Chapel Island and New World Island. The trip to this point lies within the Exploits Subzone of the Dunnage Zone, and crosses Silurian rocks of the Botwood Group, and then enters the underlying rocks of the Ordovician Dunnage Mélange. The outcrop is located at the southern end of New World Island, 9 km beyond the Reach Run causeway, just past a large sign announcing a new school commission. ***WATCH FOR TRAFFIC AT THIS LOCATION, AS THE ROAD IS NARROW AND VISIBILITY IS RESTRICTED.***

The Dunnage Mélange is a chaotic unit consisting of large blocks or "knockers" of various rock types in a black shaly matrix. Clasts vary from small cobbles to blocks up to 1 km in diameter. Many of the islands that are visible from the causeways in Reach Run and Dildo Run, as well as many of the rounded hills on Chapel Island visible from the road, are actually individual "megablocks" in the mélange. The clasts represent most of the rock types in the surrounding units. Hibbard and Williams (1979) traced a "ghost stratigraphy" from the adjacent Exploits Group. They suggested that the mélange represented an olistostrome developed in a back-arc setting, in which Exploits Group materials repeatedly slumped into an adjacent shale basin. The age of the mélange is controversial. Middle Cambrian trilobites were found in carbonate within a block, but many blocks and the matrix contains Early to Middle Ordovician (Arenig) graptolites, suggesting that it developed over this time period (Hibbard *et al.*, 1977).

Stop 3.8
Luke's Arm Fault – Expression of the Red Indian Line

From the previous stop, continue along Route 340 to a viewpoint located approximately 1 km beyond the junction of Route 340 and Route 346, also on New World Island. This stop provides a scenic view of the course of the Luke's Arm Fault, which is the local expression of the Red Indian Line, i.e., the boundary between the two subzones within the Dunnage Zone. The rocks on the opposite side of the fault, to be visited at the next stop, are volcanic rocks of the Moretons Harbour Group, presumed to represent part of an older arc developed closer to the Laurentian margin of Iapetus during the Cambrian. A paleomagnetic study of the Moreton's Harbour Group indicates that it formed at low southerly latitudes, consistent with data from the Laurentian margin (Johnson *et al.*, 1991). The fault is defined by a northeast–southwest trending lineament marked by valleys, lakes and coves on the coastline of New World Island.

Stop 3.9
The Stewart Mine at Little Harbour

From the previous stop, return to the Route 346 junction in Virgin Arm, and turn toward Chanceport and Moreton's Harbour. In the village of Moreton's Harbour, turn right toward Little Harbour. At the end of the road, parking is possible by the satellite dishes, and a well-defined trail leads northward to a meadow overlooking Little Harbour and its three islands. Cross the meadow to the trees on the north side, and the old mine dumps should be visible. It takes just a few minutes to walk up to them. The north shore of Little Harbour provides a spectacular sequence of submarine volcanic rocks of the Moreton's Harbour Group, including pillow lavas, feeder dykes, pillow breccias and tuffs. If time permits, we will examine these outcrops. There are striking volcanic features such as liquid bombs, with "splash features", and mixing textures produced during the emplacement of magmas into unconsolidated tuffaceous sediments. Little Harbour is also a very scenic location, if the weather is cooperative!

The Little Harbour mine was discovered in 1896 and worked for about 1 year, producing about 125 tonnes of arsenopyrite. The mineralized vein occurs within a 10 m-wide porphyritic diabase dyke, which is intensely altered to calcite, quartz and chlorite. The mineralization is associated with a rhyolitic dyke, but the contact between this and the mafic host rock is not exposed. The vein appears to crosscut the mafic dyke at a shallow angle. The felsic dyke outcrops immediately north of the mine shaft, and projects to intersect the mafic dyke near the outcropping veins. Arsenopyrite is the main mineral in the veins and is abundant; it is accompanied by pyrite, pyrrhotite, sphalerite and chalcopyrite. Stibnite and tetrahedrite have also been reported. A supergene alteration zone contained realgar and scorodite, but these are now rare. The gangue is mostly quartz and carbonate; the veins are sheeted, suggesting repeated opening of fractures and injection. The old mine dump provides abundant samples of the vein and euhedral arsenopyrite. This is one of several arsenic and antimony occurrences in the Moreton's Harbour area, and there were also attempts at mining some other veins in the area. It is also one of the earliest discoveries of gold in Newfoundland, although this was not the commodity of interest. Assays reported from this location by Heyl (1936) contained 12-18 g/t Au and 7-14 g/t Au. The small size of this vein limits its potential, but it illustrates a possible gold-bearing environment in this area, which remains underexplored. It is interesting in this context that New World Island is currently an active exploration area, with some interesting new discoveries of gold mineralization. However, these are mostly located on the opposite side of the island, along the shores of Dildo Run, within Exploits Subzone rocks.

Stop 3.10
Oldest and Youngest Intrusive Rocks of the Dunnage Zone

From the previous stop, return to Route 346 and drive to the historic town of Twillingate. Follow the signs to Jenkins Cove, and park at the end of the road. Walk around the seashore to the left of the parking area. The dominant rock type on the shoreline is the Twillingate trondhjemite, a sodic granitoid rock that probably formed in Cambrian island arcs located near the Laurentian margin of Iapetus. It has been dated at ~507 Ma (Elliot *et al.*, 1991), and is about the same age as trondhjemitic rocks preserved with the Taconic allochthons of western Newfoundland (Little Port Complex; Jenner *et al.*, 1991), whose emplacement supposedly results from attempted subduction of the Laurentian margin beneath these arcs. The trondjemite is cut by a 10 to 20 cm wide black lamprophyre dyke that is interpreted to record a tensional environment developed during Mesozoic times. This outcrop thus records both the early stages of the destruction of Iapetus, and the birth of its successor, the modern Atlantic Ocean.

If weather and time permits, there will be a boat excursion for viewing of icebergs and possibly marine mammals. If not, the field trip will continue, to enjoy the spectacular views from the Long Point lighthouse at the end of the road on Twillingate Island. At the lighthouse, pay attention to warning signs. ***THE CLIFFS ARE HIGH, STEEP, AND LOCALLY OVERHANGING. IT IS VERY DANGEROUS TO APPROACH CLIFF EDGES OR VENTURE BEYOND ANY FENCE, BARRIER OR NOTICE.***

DAY 4: GOLD MINERALIZATION IN THE EASTERN DUNNAGE ZONE IN THE GLENWOOD AND GANDER RIVER AREAS

Leaders : Gerry Squires, David Evan, Altius Minerals Staff, local prospectors

Geological Background

The area to be visited on Day 4 is essentially along strike from the area visited on Day 3 and the regional geology is closely similar (Figure 3.1). The projection of the Dog Bay Line runs along the southeast edge of the granites and gabbros of the Mount Peyton Intrusive Suite, dated at ~ 424 Ma (Dunning, 1994; quoted *in* Squires, 2005). The gold showings to be visited in the morning are hosted by the Davidsville Group, and resemble some of those from yesterday. The gold showings to be visited in the afternoon are mostly hosted by the Indian Islands Group. This area has attracted much exploration attention over the last few years under the label "Botwood basin", and has been described as a potential location for both epithermal-style and "Carlin-type" gold mineralization. The definition as a "basin" is not entirely accurate because the Botwood and Indian Islands groups are structurally preserved remnants of originally more extensive sedimentary sequences, rather than depositional centres. Also, the two halves of the "basin" likely represent very different (and likely geographically separate) environments, because they are separated by the Dog Bay Line, which is an important structure (*see* earlier discussion). However, the term "Botwood basin" has achieved common usage, and is likely to remain popular. Epithermal-style mineralization was initially recognized in the 1980s, and became the target of choice in the 1990s. Possible examples include the Moosehead prospect, which has given "bonanza"grades up to 278 g/t Au over 0.44 m and 91.5 g/t over 2 m (Altius Minerals, press releases). This area was the subject of an advanced exploration program, through a joint venture with Sudbury Contact Mines. Extensive epithermal-style quartz veining with associated hydrobrecciation at Rolling Pond (Barbour *et al.*, 2001) preserves a wide range of textures typical of near-surface environments, but has not yielded significant gold results. The Mustang prospect and adjacent showings have also been regarded as epithermal in character (Barbour and Butler, 2001), although other explanations have been advanced (*see below*). Showings within the Indian Islands Group have attracted interest as possible examples of carbonate-hosted ("Carlin-type") gold mineralization, and semi-calcareous rocks of the Indian Islands Group were in part the target of a regional exploration program as part of a recent Altius Minerals–Barrick Gold joint venture.

Stop 4.1
The Bullet and Knob Prospects, near Glenwood

These two closely adjacent showings are described by Evans (1996, 2001b). They are located about 500 m south of the Trans-Canada highway along a small woods road that starts in a large gravel pit developed within shales of the Davidsville Group. This access road is located 2 km east of the eastern access road to the community of Appleton, west of Gander.

The Bullet prospect is hosted by graphitic green shales and siltstones of the Davidsville Group. Gold mineralization is developed within a set of quartz-carbonate veins. The veins contain disseminated pyrite, arsenopyrite, boulangerite (?) and other base-metal sulphides. The gold occurs as specks and clusters of free gold. Results from grab samples here were locally very spectacular, ranging up to 702 g/t Au. At one time, it was relatively easy to find native gold here, but it is getting progressively more difficult!

The Knob prospect is located a few hundred metres south of the Bullet Prospect, and is accessed by walking along a disused narrow woods road unsuitable for vehicles. Here, the auriferous quartz veins are developed within a variably deformed northeast-trending greywacke unit of the Davidsville Group. The greywacke is in fault contact with an unmineralized and unaltered unit of shale. Two types of quartz veins are described by Evans (2001b). Pyrite–arsenopyrite-rich veins typically show low gold values, but milky-white massive to sheeted quartz veins that contain minor pyrite, chalcopyrite and boulangerite (?) also contain free gold. Both vein types are shear-controlled and cut the greywackes at a high angle to bedding. Extensional (tension-gash) veins are also developed within and adjacent to the main shear zones in the outcrop. There is disseminated pyrite and arsenopyrite in the wall-rocks, which appear to be silicified. The veins have yielded spectacular grades in channel samples, up to 631 g/t Au. A 13 m channel sample, consisting mostly of sheared greywacke, gave an average grade of 6.3 g/t (Evans, 2001b).

Stop 4.2
The Dome Prospect

The Dome prospect consists of quartz veins within the siliciclastic rocks of the Davidsville Group, and its overall setting resembles that of the Bullet and the Knob prospects (*see* previous stops). All three gold prospects are aligned along a prominent lineament termed the “Appleton Linear”. The Dome prospect contains free gold, and gold can be readily panned from soils and tills in and around the outcrops; thus, it has become a popular field trip stop. The exploration history of the area is summarized by Dimmell (2001). The area is accessed by a small forest access road that leads north from the Trans-Canada Highway in the community of Appleton, 400 m west of the easternmost access road to Appleton. Continue along this road for almost 3 km, then turn south on a branch road for about 1.4 km. Prominent quartz veins (the Road vein) are located at the end of the road.

Several prospects and showings are located within this general area, and all are hosted by quartz veins that cut the greywackes, siltstones and shales. The Dome Prospect consists of a prominent quartz knob that represents a sigmoidal-shaped widening of a quartz vein oriented obliquely the main northeast–southwest trend of the Appleton Linear. An area of approximately 70 square metres was tested by channel sampling, and gave an uncut grade of approximately 43 g/t Au (Dimmell, 2001). Spectacular free gold occurs on fractures or healed vein margins in nearby subsiduary veins. There is extensive iron carbonate alteration associated with the veining. The principal sulphide minerals in the veins are pyrite, chalcopyrite and a grey metallic mineral interpreted as boulangerite. Dimmell (2001) suggested that some features associated with epithermal environments were present in this area, but the similarity to the Bullet and Knob prospects implies that the mineralization is mesothermal in character.

Stop 4.3
The Outflow Prospect and Mustang Showing

The Outflow prospect is located on the western side of the outflow of the Gander River into Gander Lake, about 6.5 km south of the Trans-Canada Highway at Glenwood. The main street of Glenwood eventually becomes a logging road at the edge of the community, and leads directly to the site, which is located about 3 km along the woods road, close to its intersection with an old road. The Outflow prospect consists of two subzones termed the Piper Zone and the Mustang Zone, which were originally discovered by Noranda exploration in the 1980s. The mineralization is developed within shales, siltstones, and greywackes of the Davidsville Group, but it appears to be somewhat different in character to the mineralization seen at the Knob, Bullet and Dome prospects (*see* previous stops). The mineralization is described by Evans (1996), Churchill (1999), Barbour and Butler (2001) and Squires (2005). The Mustang showing in particular has received recent attention by Altius Minerals and joint venture partners.

Mineralization at Mustang and Piper is associated with intense silicification, which occurs within, and adjacent to, a major northeast-trending fault known as the Piper Fault. This fault is interpreted to have been the main conduit for mineralizing solutions. Three styles described by Evans (1996) based on Noranda work include stockwork-style (hydrobrecciation ?), pervasive silicification and discrete quartz veining. Vuggy quartz veins and hydrobreccias with well-developed cockade textures are present. Channel samples from the Mustang showing, which is the larger of the two zones, assayed 12.2 g/t Au; gold values for the Piper showing are typically lower. The best result from drilling at Mustang was 28 g/t Au over 0.8 m (Barbour and Butler, 2001), although values of 1-2 g/t Au are typical of much of the zone. The mineralization is associated with pyrite, arsenopyrite and stibnite, and locally is anomalous in Hg. Evans (1996) suggested that the textures observed at the Outflow prospect were consistent with an epithermal environment. Tallman (1991) suggested that the Sb-rich nature of this mineralization might indicate a link to the economically important antimony mineralization at the Beaver Brook deposit, about 30 km to the southeast (Figure 3.1). Barbour and Butler (2001) also speculated that there might be a link between the gold-bearing zone at the Outflow and the Appleton Linear, which hosts the Bullet, Knob and Dome prospects (see previous stops). The Mustang zone has been suggested to have affinities with Carlin-type mineralization, mostly by virtue of its associated geochemical signature (Altius Minerals, press releases, 2003). Recent geochemical studies of pyrites indicate that arsenic-rich pyrite, containing elevated Au, is present in the mineralization; the pyrites are also rich in Sb and Pb (O'Driscoll, 2005). Squires (2005) agreed with Evans (1996) in considering the features of the prospect to indicate a low-sulphidation epithermal environment.

Stop 4.4
The Jasperoid Showing and Adjacent Outcrops

This stop, and those that follow, are located west of Glenwood, within the Indian Islands Group. These are new occurrences that are as yet only partially explored, but they have sparked some interest in the potential of the Indian Islands Group as a host for disseminated gold mineralization in silty carbonate rocks, i.e., "Carlin-type" gold. The only public-domain descriptions of these showings are those by Squires (2005).

From Glenwood, drive south on the main logging road that leaves the TCH by the large sawmill just west of the town for about 5 km, to a point where an abandoned road branches off to the left. The Jasperoid showing is located almost 3 km down this road, which is narrow, partially overgrown and unsuitable for vehicles. It takes approximately 45 minutes to walk to the site. There is very little outcrop enroute, aside from some small exposures of Indian Islands Group sedimentary rocks. The barite showing (*see below*) is passed enroute to the Jasperoid showing, but will be visited later.

The Jasperoid showing was discovered during prospecting efforts by Altius Minerals throughout the Indian Islands Group, following recognition of fine-grained, black siliceous float containing about 1 g/t Au. The outcrop was discovered during subsequent mapping and trenching, and is named because of its apparent similarity to "jasperoids", which are silicified limestones associated with gold mineralization in the Carlin district of Nevada. Strong silicification is present in what was originally a limestone debris-flow bed containing Silurian corals, brachiopods and bryozoa. The debris-flow unit may have been preferentially altered and replaced because it was more permeable than the adjacent limy siltstone units. In the trench exposures, the original sedimentary texture is still visible on a local scale. Silicification is associated with numerous vuggy cavities lined with crystalline quartz, a texture that suggests formation in a shallow, near-surface environment. The main part of the outcrop is flanked by greenish, laminated calcareous sedimentary rocks that exhibit brown iron-carbonate alteration.

Across the old road, immediately northwest of the main showing, a set of quartz veins intrude limy siltstones and sandstones, at a high angle to the bedding. These veins contain banded colloform quartz, and bladed quartz crystals interpreted to be pseudomorphs after calcite or barite. These features, and other textures such as hydrobrecciation, are indicative of a shallow epithermal system. There is likely a connection between the Jasperoid showing and this vein system; the latter may have been the “feeder” to a stratabound replacement and alteration zone developed within the reactive carbonate beds.

The textures at these localities are spectacular, but neither the Jasperoid showing or the adjacent vein system contain high gold grades; typical assays from both indicate <1 g/t Au.

Stop 4.5
The Barite Showing

The Barite showing is located a few hundred metres north of the Jasperoid showing, along the old woods road, and was passed on the walk to the previous stop. It occurs in a large stripped area, and is easily located due to its white colouration. It is described by Squires (2005) as a subvertical vein system containing barite and quartz, oriented at a high angle to bedding in the host Indian Islands Group sedimentary rocks. No significant Au assays are reported, although it is locally anomalous in Au, Hg and Zn, and contains up to 278 g/t Ag. The quartz–barite veins display colloform textures and comb-banding, and the barite has a well-developed bladed crystal habit. Spectacular breccias are present locally. The zone was the subject of a thesis study by Lake (2004), who concluded that the barite is late, and overprints two earlier phases of quartz deposition and silicification. Galena and sphalerite are present locally, and are associated with the second period of silica deposition. Stable isotope studies indicate that the earlier, silica-dominated material was precipitated from magmatic fluids, whereas the barite itself was precipitated largely from meteroric fluids (Lake, 2004). Squires (2005) suggested that the showing has many features suggestive of an epithermal environment.

Stop 4.6
The Road Breccia Showing

The Road Breccia showing is located about 700 m northeast of the Barite showing along another abandoned woods road that branches to the east, and is described by Squires (2005). It consists of an east–west trending quartz stockwork breccia zone with a well-developed vein-like morphology, oriented essentially perpendicular to bedding in the host rocks, which are siltstones of the Indian Islands Group. The wall-rocks to the vein system exhibit strong brown iron carbonate alteration. The gold grades are low, with the best results from channel samples at 0.3 g/t Au over 1 m.

The outcrop also contains a dyke of dark green, fine-grained gabbro, which is oriented parallel to the quartz vein. The dyke retains a chilled contact with its country rocks, but it does not show any signs of alteration or mineralization; however, it lies beyond the marginal alteration around the quartz vein. Geochronological studies of this dyke have provided a U–Pb SHRIMP age of 411 ± 5 Ma (McNicol, 2005), suggesting that it is Early Devonian. Although the dyke and the quartz vein share the same orientation, this result does not directly constrain the age of mineralization.

There are no further outcrops of interest in this area. From this stop, the return walk to the main woods road takes approximately 50 minutes.

Stop 4.7
The Contact Showing

The Contact showing is located on a side road a long distance southwest of the previous stops. Continue southwest along the main road for about 4 km past the turning for the Gander River bridge, and then turn right along a smaller and much rougher road. The showing is located in the ditch on the right hand side of this road. Because of the extra driving involved, this stop may not be feasible due to time constraints. The showing is described by Squires (2005).

The contact showing is located about 400 m from the outer contact of the Mount Peyton Granite (Figure 3.1) and is hosted by altered granite. The alteration in the granite appears to be argillic in nature, and the host rocks are cut by numerous chalcedonic silica veins, associated with minor pyrite and base-metal sulphides. The mineralization is low grade, with assays of up to 1.2 g/t Au, 13 g/t Ag, 0.8% Cu, and anomalous Pb, Zn, As, Sb and Mo. Similar veining is reported to crosscut the metamorphic aureole of the Mount Peyton Granite (Squires, 2005). The Contact showing is significant in that it provides a maximum age for gold mineralization, as the granite was dated at ~ 424 Ma (Dunning, 1994, quoted by Squires, 2005). However, the geochronology sample is from a different location.

DAY 5 (Morning): MESOTHERMAL GOLD MINERALIZATION IN THE EASTERN DUNNAGE ZONE IN THE BADGER AREA

Leaders: Gerry Squires, David Evans, Rubicon Minerals Staff

Day 5 of the field trip involves two separate areas in rather different parts of the Dunnage Zone. The morning will consist of a visit to the “Golden Promise” project of Rubicon Minerals, which is an interesting new gold discovery in Ordovician sedimentary rocks in the western part of the Exploits Subzone. These rocks have generally not been considered prospective, as they contain very few gold showings, in contrast to the eastern part of the Exploits Subzone, visited on Days 3 and 4. This visit will be followed by a drive northward to scenic Green Bay, where the field trip will visit the Colchester Property of Cornerstone Resources, located north of Springdale. This is a gold-rich VMS environment centred around some 19th century copper mines, and it represents an important environment for gold mineralization in Newfoundland (*see* Section 2). The day will conclude with a drive to Baie Verte in preparation for Day 6.

Geological Background: Western Exploits Subzone

The western part of the Exploits Subzone of the Dunnage Zone is a complex region including rocks ranging in age from late Precambrian to Carboniferous, but it is dominated by Cambrian to Silurian volcanic and sedimentary rocks. The three main stratigraphic units are the Victoria Lake Supergroup, the Badger Group, and the Botwood Group (Figure 3.2).

The Victoria Lake Supergroup consists of Cambrian and Ordovician rocks. The lower section of this composite unit comprises tholleiitic and calc-alkaline volcanic rocks of mafic to locally felsic composition, which are intercalated with volcanogenic sandstones, siltstones and shales. Recent geochrononlogical and mapping work suggests that some parts of the Victoria Lake Supergroup may be of latest Precambrian age (Squires and Moore, 2004). These rocks were probably formed in various island-arc settings on the Gondwanan margin of Iapetus, and they host important VMS deposits (*see* Section 1). These are overlain by a distinctive unit of graphitic, sulphide-bearing shales, which extend across the entire region, and form a valuable marker horizon that is easily detected with geophysical surveys. This unit is generally known as the *Caradocian Shale*, by virtue of its Middle Ordovician age (460-450 Ma).

The Victoria Lake Supergroup and Caradocian Shale are overlain by the Badger Group, which consists of Late Ordovician to Silurian sedimentary rocks. These form a shallowing-upward sequence of clastic rocks including siltstones, sandstones and conglomerates. The Badger Group passes gradationally upward into the terrestrial and fluviatile red beds of the Botwood Group, of Middle Silurian and younger age. Minor felsic volcanic rocks occur in the Botwood Group, and also in the Stoney Lake area. In contrast to the Notre Dame Subzone (*see* later discussion) there is no marked sub-Silurian unconformity, and the sedimentary record appears to be largely uninterrupted. The rocks of the Badger Group are intruded by several plutons, notably the Hodges Hill and Mount Peyton intrusive suites, which are bimodal igneous assemblages of Silurian age (416 and 424 Ma, respectively). The relationship between plutonic rocks and the sedimentary rocks of the Botwood Group is not well known, as most contacts between the two are fault zones.

Stop 5.1
Botwood Group Red Beds (Wigwam Formation)

This optional stop is located at the Salmonid Interpretation Centre in Grand Falls-Windsor. From downtown Grand Falls, cross the Exploits

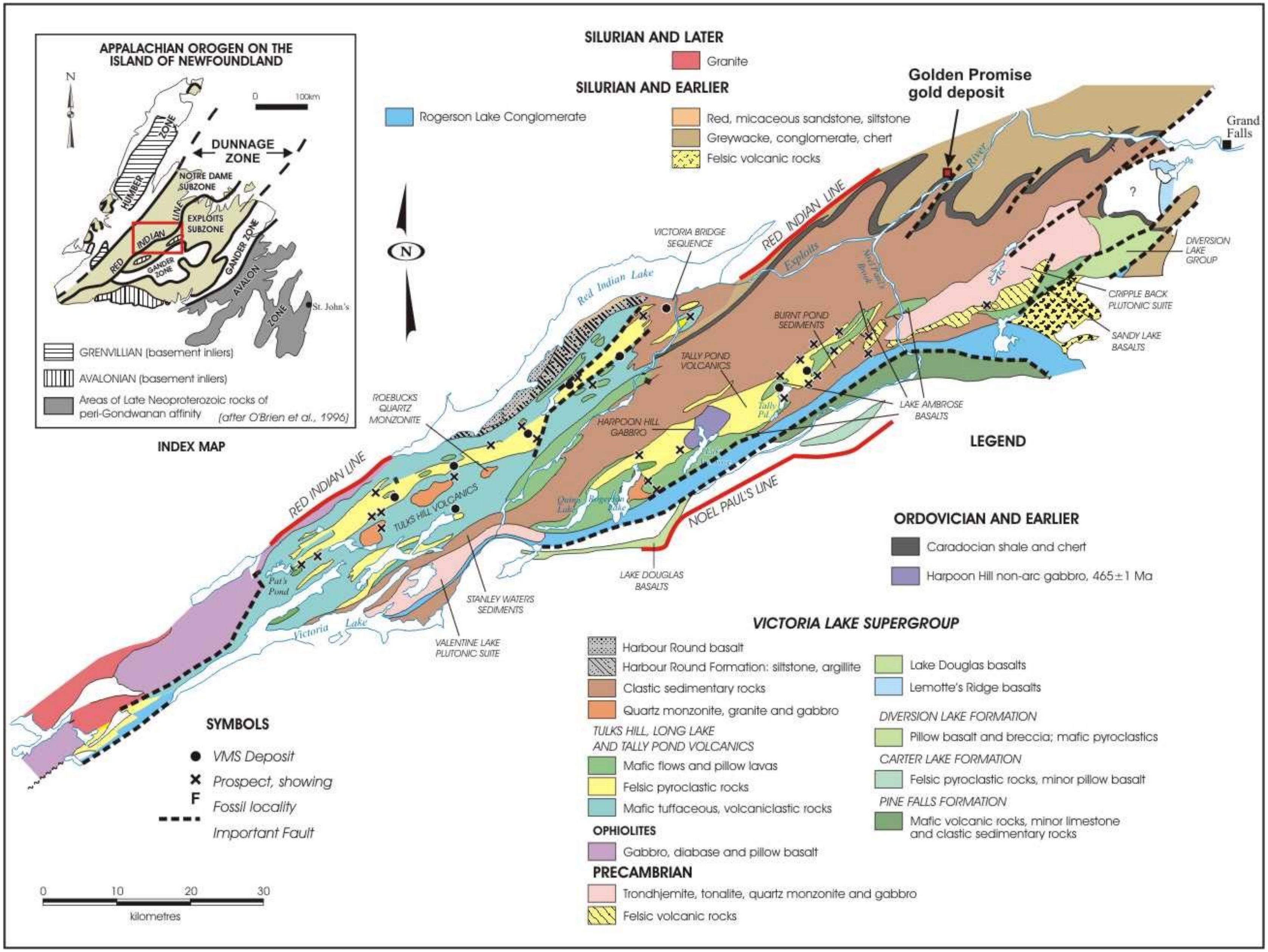


Figure 3.2. *Regional geology of the western part of the Exploits Subzone of the Dunnage Zone, in the Badger–Red Indian Lake–Victoria Lake area. Modified after Squires and Moore (2004).*

River on the narrow bridge by the paper mill, and then turn right, following the signs. The following description is adapted from Williams (1999).

The outcrops around the Centre consist of red, green, buff and grey micaceous sandstones, with a few shaley and conglomeratic interbeds. These belong to the Wigwam Formation, which is in the upper part of the Botwood Group. Regionally, these terrestrial and fluviatile sedimentary rocks overlie felsic volcanic rocks of the Lawrenceton Formation. Based on some very sparse fossil evidence in a few marine beds, the formation appears to be of Late Silurian (Ludlow–Pridoli) age. The outcrops contain well-preserved ripple marks and other sedimentary structures, such as crossbedding, mud cracks and raindrop prints (not all visible at this locality).

The Salmonid Interpretation Centre will probably be closed at the time of our visit, but it is highly recommended if you are ever in Grand Falls again!

Stop 5.2
Caradocian Shale with Sulphide-rich Beds

From Grand Falls, drive west on the Trans-Canada Highway to a roadcut outcrop located in the area known as Red Cliff, by virtue of its rusty outcrops. It is located just west of the bridge over the abandoned railway line. The outcrops on both sides of the road expose Caradocian black shales. This outcrop is visited on almost every field trip across Newfoundland and there are numerous descriptions; the following description is adapted from Williams (2001). ***BE VERY CAREFUL AT THIS LOCATION AS THE HIGHWAY IS VERY BUSY AND TRAFFIC IS FAST-MOVING. WE SUGGEST THAT YOU DO NOT ATTEMPT TO CROSS THE HIGHWAY!***

The outcrop consists of dark grey to black shales, argillites and cherts, and a few interbedded greywacke beds; these are both intruded by some intermediate dykes. The outcrop is deformed into tight upright folds. The shales are graphitic and sulphide-rich, and they are locally fossiliferous. Graptolite faunas are of Caradocian age. The western end of the roadcut contains abundant chert and argillaceous chert, and some thin massive pyrite beds. These are anomalous in base metals, but do not contain any economic mineralization.

From a regional geology perspective, this unit marks the cessation of arc volcanism across the Exploits Subzone, likely recording the final closure of the main Iapetus Ocean (*see* Section 1). Rocks of the same age on the Laurentian platform overlap the Taconic allochthons that were transported westward across the shelf, and thus bracket their final emplacement. The Caradocian interval is absent in the Notre Dame Subzone, and this time period is instead marked by a profound unconformity at the base of the Silurian sequences (e.g., the Springdale Group).

From a mineral exploration and mapping perspective, this unit is also very significant as it exhibits a strong conductivity response due to sulphides and graphite. It is a very useful marker horizon in areas of poor exposure, marking the boundary between the arc-related volcanic rocks (seen as prospective for VMS deposits) and the younger sedimentary rocks (seen as relatively uninteresting).

Stop 5.3
The Jaclyn Vein System and Adjacent Outcrops, Golden Promise Property

General Information

The Golden Promise project (a joint venture between Rubicon Minerals and Placer-Dome) is an active advanced exploration program centred upon the Jaclyn vein, discovered in 2002 in an area with no previous history of gold mineralization. The geology of the project area is summarized in a short field-trip guide prepared in 2004 (Copeland, 2004) and also by Squires (2005). Further information is provided in abstracts by Tarnocai (2004) and Copeland (2005). The following account is simplified and modified from Copeland (2004).

In the spring of 2002, local prospector Bill Mercer discovered gold-bearing quartz float in an area exposed by a major forest fire in 1999. A composite sample from several boulders assayed approximately 30 g/t Au. The property was optioned on the basis of these results, and has now undergone systematic exploration including prospecting, soil geochemistry, geophysics (mag and EM), trenching and diamond drilling (38 holes). The mineralized vein has now been traced over some 400 m, and has given spectacular grades over narrow widths including 66 g/t Au over 0.3 m and 45 g/t Au over 0.3 m. Wider intersections include 2.5 m of 16.6 g/t Au and 2.3 m of 17.7 g/t Au; a summary of drill hole data is provided by Copeland (2005).

The prospect area is located close to the Badger to Buchans Highway; a drill road branches off approximately 11.5 km southwest of the TCH junction in Badger. The prospect area is a short walk (<1 km) along the drill road. There are no outcrops along the road, but numerous float blocks expose siltstones, sandstones and conglomerates of the host sedimentary rocks, generally viewed as Badger Group. These include boulders with a distinctive "spotted" texture, which may be alteration related to mineralization or regional hornfelsing (see discussion below). There is little natural outcrop in the area, and the localities visited are large float blocks believed to be derived from subjacent bedrock, along the trace of the Jaclyn vein. This area contains many examples of visible gold, in places coarse enough to see without a hand lens. Attempts to collect such material from boulders would be completely futile, and would result only in the destruction of material. For this reason, and for the benefit of others yet to visit the site, we ask that you ***PLEASE REFRAIN FROM HAMMERING AND ATTEMPTS AT SOUVENIR COLLECTION!***

Summary of Geology and Mineralization

The auriferous quartz veins are hosted within uppermost metasedimentary rocks of the Victoria Lake Group and the overlying Caradocian shale. The mineralization was originally thought to be in sedimentary rocks of the Badger Group, but regional geophysical surveys have revised the location of the graphitic shale marker unit. The outcrop pattern of the graphtic unit, as revealed by geophysics, implies that there is tight folding through the area, which probably controls the distribution of veins and their features. The characteristics of the veining, mineralization, and alteration, resembles other better known turbidite-hosted deposits such as those of the Lachlan Fold Belt in central Victoria, Australia and the the Meguma Group, Nova Scotia (Tarnocai, 2004; Copeland, 2005). In such deposits, veins occur in "fields", broadly parallel to the structural grain, and many veins are hosted by large antiformal culminations. Regional controls are exerted by stratigraphy, such that the largest tonnage deposits occur within permeable turbidites, immediately beneath or within carbonaceous shale units. Free gold occurs within laminated fault fill quartz veins oriented parallel to bedding, large tonnage "saddle-reef" quartz stockworks and veins in the cores of folds, and as several other types of veins.

The host rocks to the mineralization are predominantly fine-grained, bedded greywacke and siltstone, intercalated with granular arkosic greywacke, and massive arkose containing siltstone clasts up to 2 cm in diameter. Primary sedimentary structures suggest an upright facing, gently north-northeast-dipping sequence. The main Jaclyn quartz vein dips steeply southeast in most areas, but dips steeply to the northwest at the eastern end, and it strikes at 070° to 090°. The vein system has a maximum true thickness of close to 4 m, with individual veins up to 2.7 m thick. The area of known gold mineralization extends to a maximum vertical depth of nearly 200 m, and is open at depth, with a presently defined strike length of 375 m. Additional drilling indicates that subparallel boulder trains that define the Jaclyn North and Jaclyn South zones are also underlain by closely similar gold-bearing quartz veins. The quartz veins are milky white to grey, comb-textured to locally vuggy, often stylolitic to banded, and are rich in inclusions. Visible gold within a given vein is generally restricted to 10-20 cm thick zones, often close to the vein margins. The most obvious gold occurs as tiny specks (<0.1 mm) to coarser flakes (3 mm) along short fractures oriented perpendicular to the vein margin; these appear to be at the margins of individual comb quartz crystals. Gold also occurs along stylolitic seams associated with fine-grained arsenopyrite, and as scattered specks along fractures parallel to the vein margins. More rarely, gold forms isolated grains in massive quartz. A 0.5 m to 1.2 m wide mafic dyke with chilled contacts cuts all rock types, including the mineralized quartz vein.

Accessory minerals include calcite, chlorite, sericite, iron carbonate, arsenopyrite, pyrite, galena, sphalerite, and chalcopyrite. Wall rock inclusions locally contain abundant arsenopyrite with lesser amounts of pyrite. Alteration associated with the veining extends for several metres to 15 m either side of the zone, but its character varies according to rock type. The most pronounced alteration is developed in fine-grained sedimentary rocks where pale green spots from 1 to 10 mm in diameter are formed. Silica–sericite–carbonate alteration is developed around fractures and locally coalesces into pervasive alteration.

Description of Field Trip Stops

The visit will commence with an examination of typical sedimentary host rocks as seen at the intersection of the drill road with the baseline. A large bedded float block contains conglomerates and sandstones typical of material seen in drill core. A nearby float block contains a diabase dyke, and possibly shows development of green “spotting” adjacent to its contacts. However, exploration work suggests that the spotting is related to the mineralized quartz veins, which share the same general trend as the dykes. Another block located a bit north of here, by a road, displays sedimentary structures including load casts. The clasts in the conglomerate are mostly felsic volcanic and granitoid rocks, as seen elsewhere in these rocks. From this point, the discovery blocks, which contain abundant visible gold, are located about 50 m to the southwest. In this area, there are numerous white quartz float blocks, all of which are gold-bearing. A distinctive “caterpillar track” texture is probably a type of “comb layering” where the crystals have grown across the vein. These “caterpillar track” zones may indicate different phases of vein formation, and they are commonly associated with high gold values. One of the blocks contains what looks like a diabase dyke some 10 cm thick. This appears to have filled in open spaces in the vein such that the original crystal faces now define the dyke contact. Some of the blocks in this area contain free gold that is coarse enough to see with the naked eye! There are also some blocks that have the “laminated” appearance typical of veins formed on the limbs of folds rather than in their hinge areas. The final part of the visit focuses on the largest of several trenches. The fine-grained siliciclastic host rocks dip gently, and there is a moderate cleavage at right angles to the trench. There is a carbonate-altered mafic dyke cutting the sedimentary rocks, parallel to this cleavage direction, which possibly represents the axial plane to local folds. If it is not completely flooded, the trench also reveals the vein and its marginal contacts.

Following the field visit, there will be an opportunity to examine typical drill core in Badger, enroute to the afternoon stops. From Badger, the excursion heads northward, and crosses the Red Indian Line (the boundary between the Exploits and Notre Dame subzones) just west of Badger, around Catamaran Provincial Park. The highway then crosses complex plutonic rocks of the Hodges Hill Intrusive Suite, before passing into Silurian sedimentary rocks of the Springdale Group.

DAY 5 (Afternoon): VMS-RELATED GOLD MINERALIZATION IN THE WESTERN DUNNAGE ZONE, GREEN BAY AREA

Leaders: David Evan, Cornerstone Resources Staff

This part of the field trip is located in the area around Kings Point, near Springdale.

Geological Background – Northern Notre Dame Subzone

The Notre Dame Subzone of the Dunnage Zone is a complex region, and the following overview is intended only to summarize the main features of the region, with emphasis on the northern section, located in the Baie Verte–Green Bay–Notre Dame Bay region. It is based to a large extent upon reviews by Swinden *et al.* (1997, 2001), with modifications reflecting some more recent ideas (e.g., Van Staal, *in press*).

The Notre Dame Subzone is bounded in the west by the Baie Verte Line, consisting of dismembered ophiolites, and in the west by the Red Indian Line, a complex series of faults marking the interface between the Laurentian and Gondwanan sides of the Iapetus Ocean (Figure 3.3). The region between these two orogen-scale structures is dominated by Cambrian and Ordovician volcanic rocks and ophiolitic complexes interpreted to represent the oceanic crust upon which these originally formed. These older vestiges of the Iapetus Ocean are overlain unconformably by Silurian volcanic and sedimentary sequences, and are intruded by a wide range of plutonic rocks, including Ordovician tonalites and Silurian bimodal intrusions. Minor Carboniferous rocks occur in the Red Indian Lake area. The Notre Dame Subzone is essentially a tectonic collage of Iapetan terranes, and the boundaries between individual volcanic belts are commonly fault zones with long and unresolved histories. The original spatial relationships between the various volcanic and ophiolitic belts are thus unknown, as are the magnitudes of later strike-slip displacements. Nevertheless, the northern Notre Dame Subzone is divisible into 4 major “belts” from northwest to southeast (Figure 3.3; after Swinden *et al.*, 1997). The *Western Ophiolite Belt* occurs mostly on the Baie Verte Peninsula (*see* later discussions), but also extends to Grand Lake in the south. It includes the ophiolites of the Advocate Complex and the Betts Cove Complex, and the associated volcanic sequences of the Pacquet Harbour and Snooks Arm groups. The Betts Cove Complex has an age of ~ 490 Ma (Dunning and Krogh, 1985). The *Western Volcanic Belt* includes most of the rocks in the Green Bay area north of the Lobster Cove Fault (Figure 3.3), notably the Lushs Bight and Cutwell groups. The rocks in the former are Cambrian, and are in fault contact with the latter, which are, in part, Early Ordovician. The older volcanic rocks likely continue eastward into the Moreton’s Harbour and Sleepy Cove groups, also of Cambrian age, which were visited briefly on Day 3 of the field trip. The Western Volcanic Belt is bounded to the southeast by disrupted ophiolitic rocks of Ordovician age, termed the *Eastern Ophiolite Belt*, most of which remain poorly known due to their inland locations and pervasive low-grade metamorphism. These have given dates of ~ 480 Ma (Dunning and Krogh, 1985), and are thus younger than the Western Ophiolite Belt, or the intervening volcanic rocks. The southeastern edge of the Notre Dame Subzone is mostly formed by the *Buchans–Roberts Arm Belt*, which is a linear, semicontinuous belt of mafic and felsic volcanic rocks, with lesser amounts of sedimentary rocks. The belt includes the Buchans Group in the south and the Roberts Arm Group in the north. This volcanic belt includes a greater proportion of felsic volcanic rocks than the Western Volcanic Belt, and it includes many calc-alkaline rocks in addition to

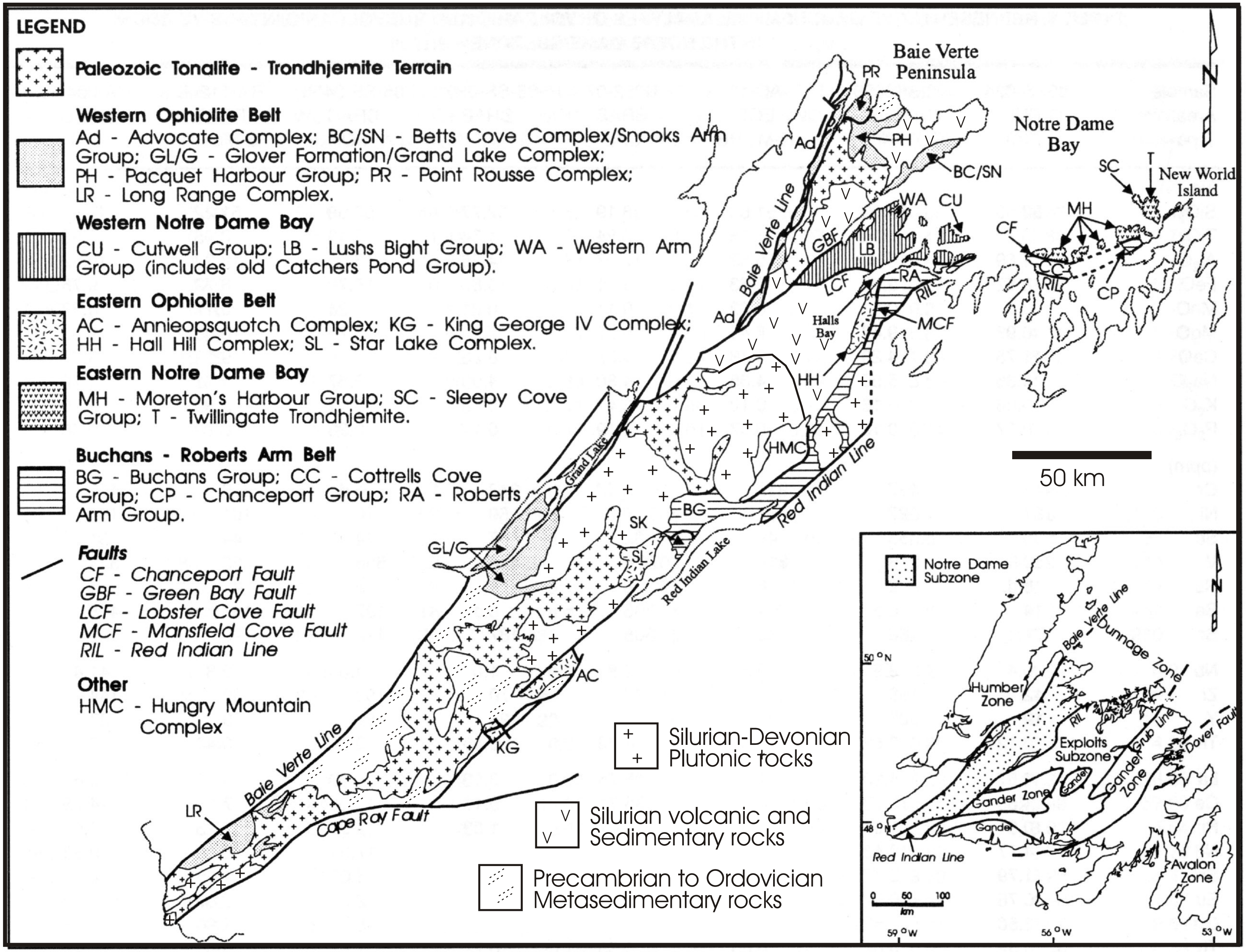


Figure 3.3. *Regional geology of the Notre Dame Subzone of the Dunnage Zone. Modified after Swinden* et al. *(1997).*

tholeiitic mafic rocks. Geochronological data suggest that these rocks formed at ~ 475 Ma, which is consistent with sparse faunal evidence.

The various ophiolitic and volcanic belts within the Notre Dame Subzone were assembled to the margin of Laurentia during the Ordovician, and the entire region was then uplifted and eroded prior to the deposition of the Silurian cover sequences represented by the Springdale Group and correlative sequences. The spectacular basal conglomerates of the Springdale Group provide evidence of this process. Section 1 of this guide summarizes plate-tectonic models proposed to explain the geological history of the region. There are plutonic suites of Ordovician age, notably in southwestern Newfoundland. These are of tonalitic to granodioritic composition, and may represent the products of Middle to Late Ordovician subduction beneath the accreted arc terranes (e.g., Van Staal, *in press*). There are also abundant plutonic suites of Silurian age, including peralkaline granite batholiths that are atypical of modern arc environments; these are in part deep-level equivalents of Silurian volcanic suites such as the Springdale Group.

From a metallogenic perspective, the Notre Dame Subzone is best known for its VMS deposits, which occur in all of the belts described above. The Buchans–Roberts Arm Belt hosts the world-class polymetallic VMS deposits of the Buchans Camp, and the Green Bay area is host to several Cu-rich VMS deposits that are also auriferous. Epigenetic gold mineralization also occurs in several areas; these deposits include the productive Nugget Pond and Hammerdown mines. The base-metal and gold deposits of the Green Bay area are mostly summarized by Kean *et al.* (1995) and by Evans (2004).

Stop 5.4
Springdale Group Basal Conglomerates

After leaving the Trans-Canada Highway at the Springdale junction, turn right, and then turn left on the road towards Kings Point and Harry's Harbour. About 1.7 km from this junction, there is a prominent set of roadcuts at the crest of a hill. ***BE CAREFUL HERE AND WATCH FOR TRAFFIC, AND EXERCISE CAUTION CROSSING THE ROAD!***

These outcrops provide spectacular exposures of the lower conglomeratic unit of the Silurian Springdale Group. The Springdale Group consists of felsic volcanic, mafic volcanic and terrestrial sedimentary rocks that sit unconformably upon the deformed Cambro-Ordovician volcanic sequences of the western Dunnage Zone (Notre Dame Subzone). The conglomerates here contain a wide variety of volcanic, sedimentary and plutonic clasts that attest to the profound sub-Silurian unconformity by providing a diverse collection of Ordovician rock types.

Stop 5.5
The Colchester Project (former Colchester and McNeily Mines)

From the previous stop, continue toward Kings Point, then turn right again toward Harry's Harbour. The road is now passing through Cambro-Ordovician mafic volcanic rocks representing island arcs developed on the Laurentian side of Iapetus. A gravel road located about 12 km from the junction in Kings Point leads to the old Colchester and McNeily mines.

The Colchester project of Cornerstone Resources and Sudbury Contact Mines is located in the Green Bay area, east of the community of Kings Point, about 2 km south of the southwest arm of Green Bay (Figure 3.3). The project is centred upon two small 19th century copper producers (the Colchester and McNeily mines), both of which exploited Cu-rich zones in chloritic schists forming part of the Cambrian Lushs Bight Group. Kean *et al.* (1995) provide an interesting account of the exploration and development history of these deposits, which only produced about 1000 tonnes of copper ore in total. The Colchester deposit, for which three separate shafts were developed, retains the largest confirmed reserve (about 1 million tonnes at 1.3% Cu), and has been the subject of several exploration programs aimed at copper since the 1930s. The geology and mineralization are reviewed by Kean *et al.* (1995), from which the following summary is adapted and simplified. The mineralization at Colchester is generally considered to represent deformed stockwork–feeder pipe alteration zones associated with Cu-rich VMS lenses.

The McNeily deposit is located near the contact of a small granitoid pluton (the Colchester granodiorite), that intrudes altered and schistose mafic metavolcanic rocks of the Lushs Bight Group. The Colchester granodiorite was dated at ~ 465 Ma (Szybinski, 1995). Strong alteration and deformation of the Lushs Bight host rocks is related to a northeast–southwest-trending fault system, which extends also to the nearby Colchester deposit, and possibly to the Old English prospect (*see below*). The copper ore consists mostly of veinlets and stringers of chalcopyrite and pyrite in sheared chloritic mafic agglomerate and breccia, with most of the sulphides in the matrix. Minor sphalerite and pyrrhotite are also reported. Kean *et al.* (1985) also report white, siliceous rocks representing either intense silicification or thin felsic pyroclastic units. Massive sulphides with banding were reported in earlier exploration programs reviewed by Kean *et al.* (1995). Numerous barren felsic and mafic dykes intrude the mineralized schists. The Colchester deposit is hosted by similar sheared chloritic mafic volcanic rocks, is also cut by numerous barren mafic to felsic dykes, and is also located close to the margin of the Colchester granodiorite. The mineralization is dominated by chalcopyrite and pyrite, and is present in several steeply plunging *en-echelon* lenses within a wider schistose zone. Sulphides occur as blebs, disseminations, stringers, veins and irregular masses. Similar mineralization at reported from the Old English Prospect, about 3 km northeast of Colchester and McNeily. The Cu mineralization in the area of all three deposits has long been known to carry interesting amounts of gold, and visible gold was reported by some early workers. However, gold was only rarely analyzed in previous exploration programs, and there was no systematic assessment of gold potential.

Cornerstone Resources acquired the property in 2001, and demonstrated a strong association between Cu and Au in the mineralization via field work and resampling of archived core. Details of the mineralization and subsequent exploration programs are reported in several press releases (Cornerstone Resources, 2002, 2003, 2004). Grab samples returned up to 11 g/t Au, associated with 2.9% Cu, and resampling of old drill holes completed by Noranda at McNeily revealed two separate intervals grading 7 g/t Au over 3 m. New mineralized localities containing up to 16 g/t Au were discovered in the Old English area, and massive sulphides containing significant Zn and Au were found in other parts of the property, as suggested by earlier work. A drill program was completed in 2004, to test the 3.5 km-long corridor of alteration and Cu-mineralization linking McNeily and Old English for its gold potential. Results provided interesting results (e.g., 5.6 m of 3% Cu and 0.5 g/t Au), but no multigram gold interesections were reported. The property is regarded as having considerable potential for both Au-rich VMS deposits and shear-zone hosted mesothermal gold deposits.

This field trip stop will include examination of several old and new mineralized localities, and an examination of new drill core from the 2004 program. Full details will be provided separately during the visit, courtesy of Cornerstone Resources.

Stop 5.6
Virginite Outcrops at Flatwater Pond

From the previous stop, continue to the Springdale access road, and then to the Trans-Canada Highway. Travel west on the highway to the next junction, and take the road towards Baie Verte (the Dorset Trail). Follow this road to a point just south of the junction for Westport and Purbecks Cove, where there are outcrops on the west side of the road displaying a strong green colouration. ***BE VERY CAREFUL HERE AS THE TRAFFIC IS FAST AND VISIBILITY IS RESTRICTED!***

These exposures consist of quartz–magnesite–fuschite rocks that represent metasomatized ultramafic rocks. The ultramafic rocks form part of the string of dismembered ophiolites that define the Baie Verte Line, which is the boundary between the Notre Dame Subzone and the Humber Zone. The ultramafic protolith has been transformed by the introduction of $CO_{2,}$ SiO_2 and minor K_2O. The green colour is imparted by chromium-bearing mica (Fuschite), which contains 4% to 8% Cr_2O_3. These outcrops are the source for ornamental stone used widely in the local craft industry.

Rocks of this general type have a number of names around the world. They are sometimes called “listwaenites” after a locality in Wales, and are also known as “mariposites” in California. In Newfoundland, they are known as “virginites”. This informal name was coined by Norman Peters, a well-known prospector and geologist who discovered many mineral deposits in this area. The derivation of this unusual name is best preserved for verbal discussions. It is, however, a credit to the influence of Newfoundland geology that this name is increasingly used elsewhere in the world for quartz–magnesite–fuschite rocks.

On a more serious note, metasomatized ultramafic rocks of this type elsewhere in the world are known to be auriferous, or to be associated with gold mineralization. These particular examples do not contain any gold or sulphides, which is probably a good thing, because the latter would rust and render the material useless for stonecraft.

DAY 6: GOLD MINERALIZATION IN THE BAIE VERTE PENINSULA AREA

Leaders: David Evan, Anaconda Mining Staff

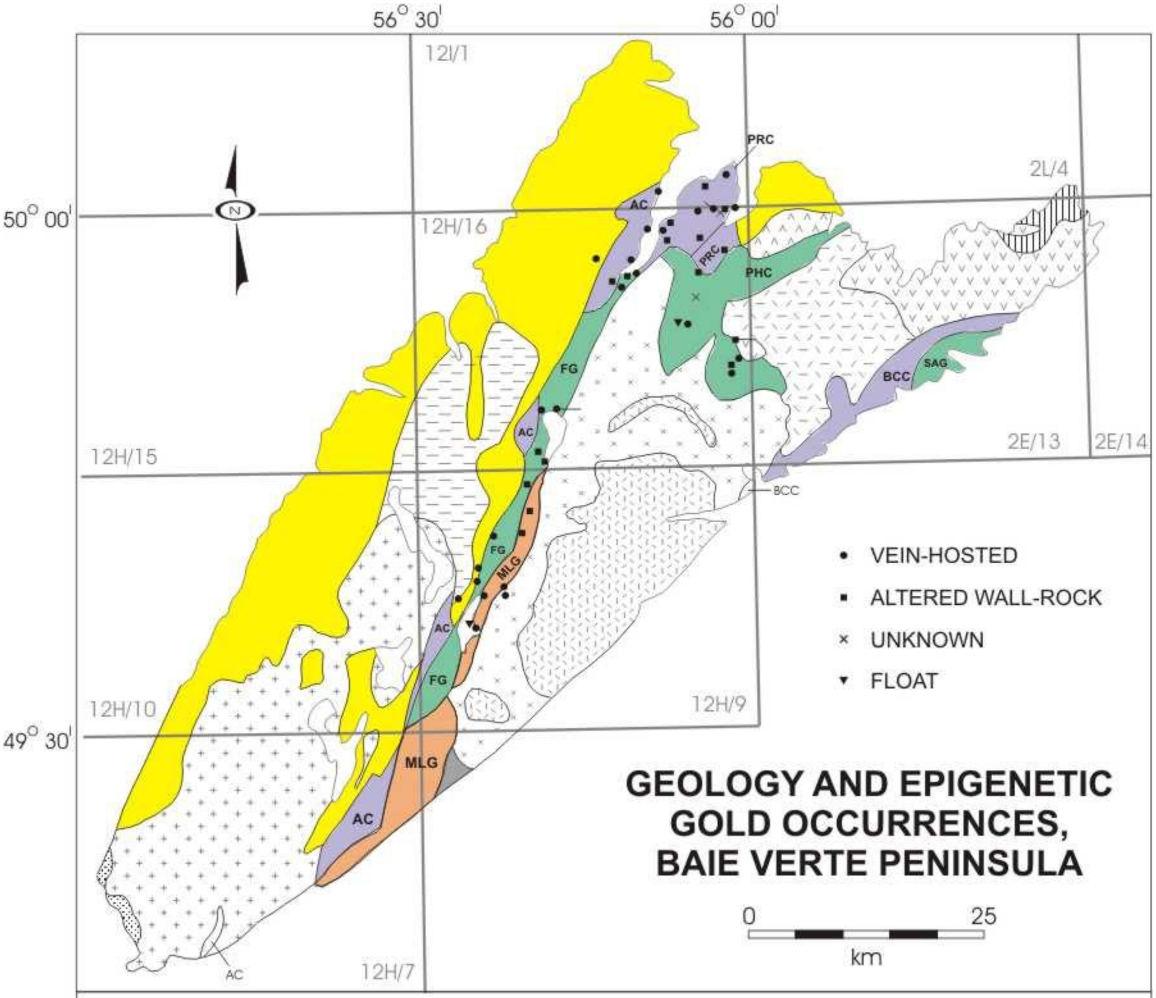
Day 6 of the field trip will focus upon the gold mineralization of the Baie Verte Peninsula in northwestern Newfoundland (Figures 3.3 and 3.4). This area has the longest history of mining activity of any region in Newfoundland, beginning with the extraction of soapstone near Fleur-de-Lys over 2000 years ago by the Dorset Eskimo culture. Modern mining activity started in the 1860s, at the Terra Nova Mine, and the area subsequently produced base metals and gold from several VMS deposits, and asbestos from the altered ophiolites of the Baie Verte Line. The area also saw some of the first discoveries of gold on the island (at Ming's Bight), and early gold production (158 ounces) from the Goldenville Mine. The rich history of mining activity on the peninsula is reviewed in detail by Martin (1983), Hibbard (1983) and Evans (2001, 2004). The latter references provide the main sources for this section of the guide.

The Baie Verte Peninsula contains a large number of gold prospects, and it is impossible to visit all in a single day. The field trip instead visits several accessible locations that illustrate the variety of mineralization styles in this important area. The field trip will also visit the Pine Cove project of Anaconda Minerals and New Island Minerals, which will enter production as Newfoundland's newest gold mine late in 2005 or early in 2006. The Nugget Pond Mine has now closed, and underground or surface visits are no longer possible. This is unfortunate, because it is a very interesting and unusual deposit; however, samples of mineralization and rock types will be available in Baie Verte.

Geological Background

The Baie Verte Peninsula includes parts of the Humber Zone and the Dunnage Zone (Notre Dame Subzone). These contrasting geological terranes are separated by the important structure known as the Baie Verte Line, which is defined by numerous faults and dismembered ophiolite suites (Figure 3.4). The Baie Verte Line is traditionally regarded as the ancient continent–ocean interface on the western side of Iapetus, although recent models introduce complexities to such models (*see* Section 1). The regional geology of the peninsula is described by Hibbard (1983) and reviewed by Evans (2001, 2004). The following account is simplified from these three sources.

The area to the west of the Baie Verte Line is underlain mostly by polydeformed metasedimentary rocks of the Fleur-de-Lys Supergroup, which mostly underwent amphibolite- facies metamorphism. These rocks represent a late Neoproterozoic to Early Ordovician continental-rise prism which developed along the eastern margin of Laurentia, but was subsequently "subducted" beneath accreted arc terranes. Some of the highest-grade rocks in this area (the East Pond Metamorphic Suite; Hibbard, 1983) may actually represent reworked Laurentian continental basement. In the northeast, these metasedimentary rocks are structurally interleaved with metamorphosed ultramafic rocks, but their original relationships to possible oceanic crust are uncertain. On a regional perspective, the Fleur-de-Lys Supergroup is the deep-water equivalent of the clastic and carbonate rocks that form the platformal cover sequence of Laurentia, and its unmetamorphosed equivalents are preserved in the Taconic allochthons of western Newfoundland (*see* Section 1). The western part of the peninsula is intruded by abundant Silurian K-feldspar megacrystic granitoid rocks of the ~ 427 Ma Wild Cove Pond Intrusive Suite (Hibbard, 1983) and also peraluminous leucogranites of probable anatectic origin.



LEGEND

AGE	FLEUR DE LYS BELT	BAIE VERTE BELT
Carboniferous		▩ Conglomerate and sandstone
Silurian to Devonian	+ + Wild Cove Pond Igneous Suite	Intrusive Rocks ▥ La Scie Intrusive Suite, ⟋ Cape Brule Porphyry (includes undivided extrusive phases) ⋰ Kings Point Complex (includes undivided extrusive phases), and × Burlington Granodiorite Extrusive Rocks v v v Cape St. John Group MLG Mic Mac Lake Group
Ordovician		Intrusive Rocks ^ ^ ^ Dunamagon Granite Extrusive Rocks FG Flat Water Pond Group SAG Snooks Arm Group
Neoproterozoic to Middle Ordovician	🟨 Fleur de Lys Supergroup	AC Advocate Complex PRC Point Rousse Complex PHC Pacquet Harbour Group BCC Betts Cove Complex
Neoproterozoic and Earlier	– – East Pond Metamorphic Suite	

Figure 3.4. *Generalized geology of the Baie Verte Peninsula, after Hibbard (1983) and Evans (2004).*

The Baie Verte Line is a structurally complex zone containing dismembered, altered and metasomatized ultramafic rocks. The rocks to the east of the Baie Verte Line consist of four main "packages", which are described in turn below.

1. Three variably preserved Cambro-Ordovician ophiolite sequences, termed the Advocate, Point Rousse and Betts Cove complexes (Figure 3.4). Some volcanic rocks of the Pacquet Harbour Group are also considered to represent the upper part of an ophiolite complex, based on correlation of distinctive Mg-rich volcanic rocks (boninites) with those of the Betts Cove Complex. The Betts Cove Complex is generally considered to be one of the most complete oceanic crustal sections in Newfoundland, although it is certainly not the most famous ophiolite. It is dated at ~ 488 Ma (Dunning and Krogh, 1985).

2. Middle Ordovician and older volcanic cover sequences, developed on these ophiolite complexes. These include the Snooks Arm Group, Flatwater Pond Group, parts of the Pacquet Harbour Group and a few other small areas elsewhere (Figure 3.4). These volcanic rocks are interpreted to represent island-arc volcanic sequences generated upon the oceanic crust represented by the ophiolites, which were also probably developed in supra-subduction-zone environments on the complex Laurentian margin of the Iapetus Ocean.

3. Silurian cover sequences of the Mic Mac and Cape St. John groups, which consist of mafic to felsic volcanic rocks and terrestrial to fluviatile sedimentary rocks (Figure 3.4). As in other parts of the Notre Dame Subzone, these rocks sit unconformably upon the older, deformed Ordovician volcanic sequences. They resemble other Silurian sequences such as the Springdale Group (*see* earlier stops).

4. Plutonic suites of dominantly Silurian age, notably in the southern part of the peninsula (Figure 3.4). These intrude the Ordovician rocks and at least some of the Silurian rocks. Important plutons include the Burlington granodiorite (~ 432 Ma), the Dunamagon granite (~ 429 Ma), the Kings Point Complex, the Cape Brule porphyry and several smaller bodies. Silurian hypabyssal plutonic rocks of the Kings Point Complex and Cape Brule Porphyry are probably genetically related to the Silurian felsic volcanic sequences of the MicMac Lake and Cape St. John groups.

The Baie Verte Peninsula has a complex deformational history including Ordovician (Taconic), Silurian (Salinic) and Acadian (Devonian) events. The initial westward emplacement of ophiolites and island-arc volcanics over the western metasedimentary terrane took place in the Middle Ordovician, but much of the pervasive deformation in both west and east is of Silurian age. The uplift of the western belt probably took place during these later events, as many of the reverse faults along the Baie Verte line hae west-side-up geometry. Although there are no Carboniferous rocks on the peninsula, it is likely that major structures such as the Baie Verte Line were sites of Carboniferous strike-slip motions.

The Baie Verte Peninsula has been the site of 12 mining operations, and a thirteenth is soon scheduled for production. Nine of these operations were for base metals in VMS-type deposits, some of which also produced significant gold as a by-product (*see* Table 1.1). The VMS mineralization is not discussed further here. The Goldenville Mine was one of the very first gold producers, but most subsequent non-VMS gold production came from the the Nugget Pond Mine. Interest in the gold potential of the peninsula grew significantly following the 1984 discovery of Hope Brook in southwestern Newfoundland. The Baie Verte Line drew interest because it is a structurally complex zone containing ultramafic rocks, analogous in many respects to the motherlode district of California. Evans (2004) provides an outline of the similarities between these two areas, which include early emplacement of allochthons across the continental margin, followed by renewed subduction and the development of a major lineament containing dismembered ophiolites between two contrasting terranes. Noranda discovered the small Deer Cove deposit in 1986, and the next four years saw the discovery of over 100 gold occurrences. These include the Nugget Pond deposit, where epigenetic gold is concentrated in a thin sedimentary horizon within the Snooks Arm Group, and the Stog'er Tight and Pine Cove deposits, where gold is concentrated in altered gabbroic rocks.

Evans (2001, 2004) divided the gold mineralization into two fundamental classes, i.e., vein-hosted and wall-rock-hosted. The vein-hosted type can be further subdivided into three subclasses, as follows:

1. Quartz–gold vein subclass, characterized by free gold in quartz with little or no sulphides.

2. Quartz–pyrite vein subclass, characterized by the presence of pyrite, in which gold is present as inclusions in sulphides.

3. Base-metal-rich quartz vein subclass, containing pyrite, base-metal sulphides (typically chalcopyrite, sphalerite and galena) and local free gold.

The wall-rock-hosted (replacement) gold deposits can be further subdivided into four subclasses, based on the typical alteration and gangue mineralogy, as follows:

1. Carbonate–quartz–pyrite replacement subclass, characterized by proximal iron-carbonate alteration and distal chlorite–carbonate alteration. The gold is typically present as inclusions in pyrite.

2. Silica–sulphide replacement subclass, characterized by pervasive silicification and variable sericitization, and pyritic sulphides.

3. Talc–magnesite–magnetite replacement subclass, characterized by shear-controlled talc–magnesite–dolomite alteration in ophiolitic host rocks. Magnetite and free gold occur, but sulphides are less common.

4. Red albite–ankerite–pyrite replacement subclass, characterized by proximal red albite–pyrite alteration associated with gold, and complex distal alteration including chlorite, ankerite and calcite.

All of these deposit types correspond broadly to mesothermal, or “orogenic” gold deposits, with the possible exception of the silica–sulphide replacement subclass, which occurs mostly in Silurian subaerial volcanic sequences. This mineralization may have affinity to low-sulphidation epithermal gold deposits.

Stop 6.1
Sample Display – Nugget Pond Mine

The field trip will not visit the Richmont Mines Nugget Pond Mine, as there is little to see on the surface. However, there will be some samples available for examination and discussion, if time permits. The Nugget Pond deposit is a very interesting small gold deposit that contained 488,000 tonnes at an average grade of 12.4 g/t (0.36 oz/ton). There are relatively few descriptions of the deposit, and the following summary is based upon the overview by Sangster and Pollard (2001). The mineralization at Nugget Pond is hosted in a thin turbidite–sandstone–iron formation within the Snooks Arm Group, which overlies submarine mafic volcanic rocks of the Betts Cove Ophiolite. The Nugget Pond Horizon separates two thick sequences of mafic volcanic rocks. Gold mineralization is associated with a complex network of quartz–albite–carbonate veins that cut the sedimentary rocks of the ore horizon, but have a broadly stratabound spatial distribution. Gold is associated with pyrite in several different forms, ranging from vein-hosted mineralization to a more diffuse replacement type of mineralization. The latter is also broadly stratabound within the sedimentary horizon, and formed the bulk of the ore. The gold mineralization is closely associated with pyrite, but there are also minor amounts of chalcopyrite, galena, Ag–telluride and native Ag. Spectacular mineralization containing large pyrite cubes in dark grey argillitic sedimentary rock results from replacement of synsedimentary or diagenetic pyrite in the host rocks. The gold occurs as inclusions and along fractures in the pyrite but, as the name suggests, there are locally some very impressive and beautiful examples of free gold in the form of wires, sheets and crystals.

The principal alteration mineral at Nugget Pond is stilpnomelane (iron-rich mica), associated with calcite, ilmenite, sphene and pyrite. Alteration is controlled to a large extent by the boundaries of the sedimentary unit, and is far less evident in the mafic volcanic footwall rocks.

Sangster and Pollard (2001) suggest that the deposit formed via sulphidation of magnetite-rich and pyrite-rich zones in the Nugget Pond sedimentary horizon, and that the fluids were related to the quartz–feldspar–carbonate veins, which have essentially the same distribution as the gold, but also extend into the footwall sequence. A single grain of xenotime from one of these veins gave a U–Pb age of 374 ± 8 Ma, which is taken to represent the timing of mineralization (R. Parrish, quoted by Sangster and Pollard, 2001).

Nugget Pond achieved fame (or notoriety) in the late 1990s when criminal charges were laid against several employees of the company, following reports of sales of spectacular gold samples believed to be derived from the deposit. These samples were collected during routine mining operations and sold privately on the basis of their aesthetic value to mineral collectors, which far exceeded the value of the gold itself. Not surprisingly, the case generated lively debate within the Newfoundland geoscience community.

Stop 6.2
The Scrape Thrust – Boundary of the Point Rousse Ophiolite

From Baie Verte, take the La Scie Highway, and then go north on the access road to the community of Mings Bight, which is signposted. The outcrops are located about 3.4 km north of the Mings Bight junction. The following description is adapted from an earlier guidebook (Evans and Kerr, 2001). ***BEWARE OF TRAFFIC ON THE HIGHWAY!***

The geology of the Point Rousse ophiolite complex and surrounding areas is indicated in Figure 3.5. At this locality, talc–carbonate schists (derived from ultramafic rocks) are thrust southeastward over the Pacquet Harbour Group mafic volcanic rocks, which are converted to strongly schistose rocks that contain tectonic banding. This is probably a Silurian structure, but it may have an earlier Ordovician history. About 100 to 200 m south along the road, a thrust of similar attitude occurs within the Pacquet Harbour Group and is likely a related structure. The Point Rousse Ophiolite Complex is imbricated and dissected by similar south-directed thrust faults. These faults appear to be spatially linked to the principal gold deposits such as Pine Cove, Romeo and Juliet, Stog’er Tight and Deer Cove (Figure 3.5).

Stop 6.3
The Goldenville Mine

From the previous stop, continue toward Mings Bight. The junction for the access road to the Deer Cove gold deposits is on the southern edge of the village of Mings Bight. Continue north along this road. The road towards the Deer Cove area is rough, and may not be suitable for low-clearance vehicles. The Goldenville mine is a very short walk (10 minutes) along a signposted but unfortunately unmaintained trail, about 1.7 km north of the junction with the Mings Bight road. The local geology and mineralization at the de-

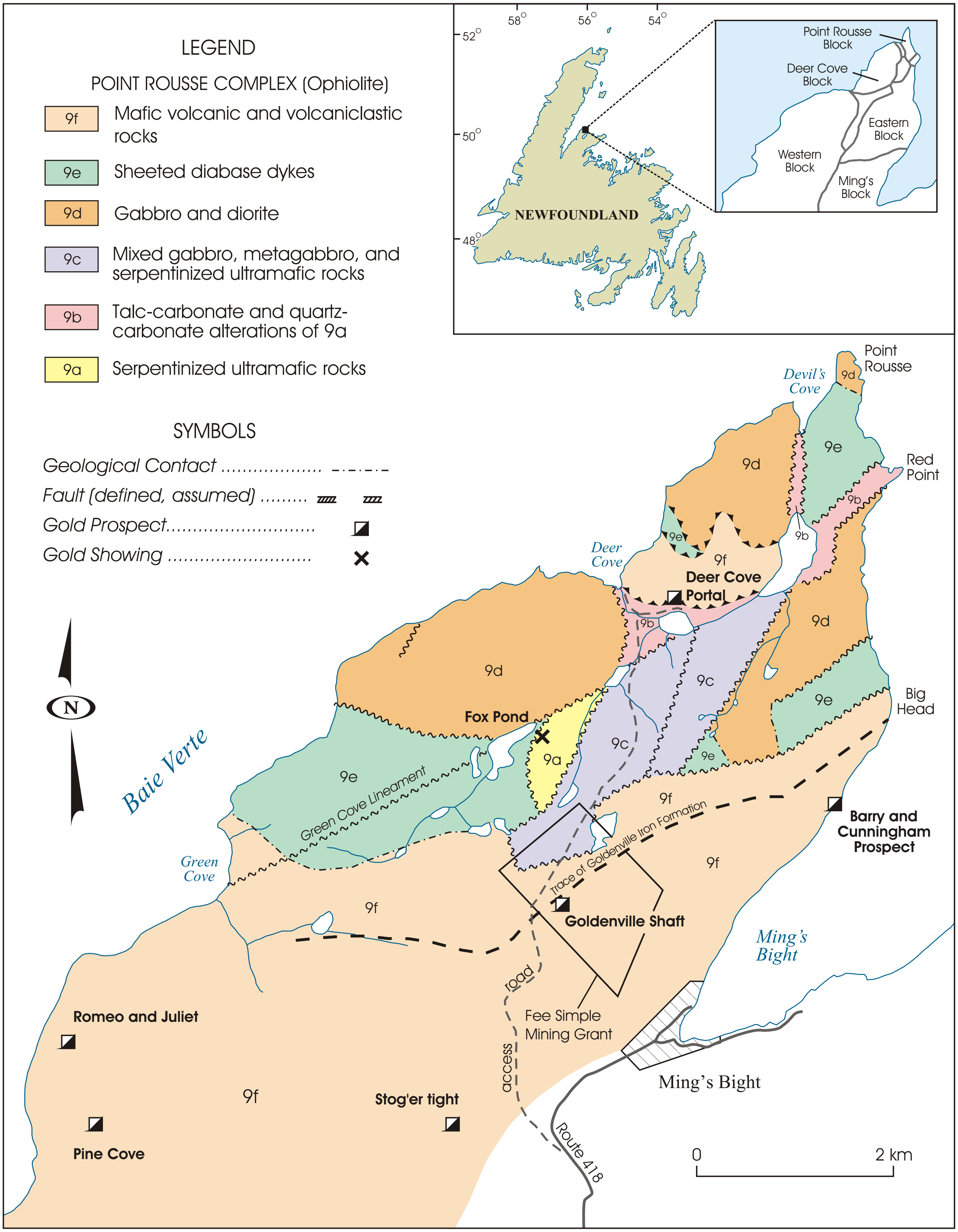


Figure 3.5. *Simplified geological map of the area between Baie Verte and Mings Bight, showing locations of gold occurrences and field trip stops. From Evans (2004).*

posit are summarized by Evans (2004), who also provides some fascinating historical accounts of early mining operations. The following account is summarized from that source.

The Goldenville deposit is hosted within a regionally extensive, but discontinuous unit of Fe-rich chert and iron formation termed the Goldenville Horizon. This horizon also hosts several other minor gold showings. This horizon sits between two sequences of mafic volcanic rocks, including pillow lavas and pillow breccias, and is generally less than 10 m in total thickness. At the mine, high-angle faults cut the Goldenville Horizon; these host pyrite-bearing quartz veins away from the sedimentary rocks, and these veins contain up to 3 g/t Au. Where the faults cut oxide-facies iron formation, magnetite has been extensively pyritized; pyrite occurs as disseminations, small veinlets and semi-massive material. Grades in grab samples vary widely from <1 g/t Au to over 200 g/t Au. The best result from an exploration drilling program in 1988 was 1.8 m at 12.4 g/t Au (Evans, 2004). The mineralization at Goldenville is considered to be of “non-stratiform banded iron-formation-hosted” type (Kerswill, 1993) as the gold is essentially restricted to late structures and veins that crosscut local stratigraphy. The setting of the Goldenville deposit is in many respects reminiscent of that of the Nugget Pond deposit in the Betts Cove–Snooks Arm sequence (Sangster and Pollard, 2001).

The outcrop is not extensive in the Goldenville Mine area, but it is possible to see the sedimentary host rocks and typical examples of mineralization are present in several old spoil heaps. The site is also interesting for examples of early machinery, which are old enough to be considered industrial archeology resources rather than junk.

Stop 6.4
The Deer Cove Gold Deposit (Exploration Adit)

This stop is located at the end of the road that passes the Goldenville Mine site (*see* previous stop). The road is not maintained and is likely to be rough. The final section involves a steep descent and may be impassable due to washouts and other damage. This stop will be omitted if there are problems with access. The Deer Cove deposit, discovered by Noranda in the mid 1980s, proceeded to advanced exploration including the development of an adit. The total resource here is fairly small, totalling some 144,000 tonnes at 4.6 g/t (Noranda, quoted by Evans, 2004). The geology and mineralization are described by Gower *et al.* (1990), Dubé *et al.* (1993), Patey and Wilton (1993) and by Evans (2004). The following account is summarized from these sources, and the field stop description is adapted from the guidebook of Swinden *et al.* (1990).

Geology and Mineralization

The Deer Cove deposit is located in a structurally complex setting where mafic volcanic rocks, sheeted dykes and gabbros of the Point Rousse Ophiolite Complex are thrust over talc–carbonate rocks representing altered ultramafic rocks. The zone along which these blocks are juxtaposed is called the Deer Cove sole thrust, and it records southward movement of the upper block, probably during the Silurian. The footwall sequence contains serpentinites, talc–carbonate rocks, and local virginite zones akin to those visited on the Baie Verte highway. The hanging-wall sequence consists mostly of mafic volcanic rocks, but also includes gabbro and diabase. The main mineralized zone consists of discontinuous lenses of brecciated quartz and veins of similar material developed in the upper (mafic) block above the sole thrust. Pyrite, with lesser amounts of arsenopyrite and chalcopyrite, is present in the veins, the wall rocks and in inclusions. Gold occurs both as free grains and as disseminated inclusions in sulphide minerals; the best grades were reported from those parts of the vein system closest to the sole thrust. A well-developed alteration halo is present around the veins. The immediate wall rocks and vein selvages display sericitic alteration, which grades outward into a wider zone of propylitic alteration characterized by chlorite, epidote, carbonate and minor leucoxene. There is a clear spatial association between the mineralization and the sole thrust, implying that the two must be linked, but the main mineralized zone also appears to crosscut related structures. Gower *et al.* (1990) and Dubé *et al.* (1993) suggest that mineralization occurred following initial juxtaposition and imbrication of the two blocks, but prior to the final motions on the sole thrust.

Several models for the Deer Cove deposit have been proposed. Gower *et al.* (1990) favoured a “listwaenite” model (e.g., Buisson and LeBlanc, 1985) in which the Ordovician obduction and serpentinization of ultramafic rocks promoted later mobilization of gold-bearing fluids from these sources into permeable or dilational zones associated with Silurian thrusting. “Listwaenite” is another name for virginite, which is present in the footwall sequence, as are talc-carbonate schists. Patey and Wilton (1993) instead argued for mineralizing fluids generated during Siluro-Devonian metamorphism at depth, based largely on isotopic evidence. Dubé *et al.* (1993) suggested that the brecciated textures so typical of the quartz veins resulted from sudden decompression of gold-bearing fluids within zones of extension.

Field Trip Stops

The field trip stops are located at the portal for the exploration adit, and on the hillside above it. The rocks at the adit portal are a serpentinite mélange marking the contact zone between hanging-wall mafic volcanic rocks and footwall ultramafic rocks. The discovery outcrop for the main zone is located immediately above the adit portal. The main mineralized zone is best seen behind the portal, after climbing the hill. Here, brecciated quartz veins run in a north–south direction, and have been exposed by stripping and trenching. The wall rocks are silicified and pyritized, whereas vein selvages and inclusions are locally sericitic. The south end of the zone contained spectacular visible gold but this is now hard to find. The main mineralized zone can be followed for about 200 m to the north; from here, a second locality (AK-2 zone) is accessed by a short descent, followed by a left turn. This zone contains similar brecciated quartz veins, but these are relatively poor in sulphides compared to the main zone. They contain fine-grained, dispersed, free gold. The veins are controlled by a sheared contact between the host gabbro and adjacent volcanic rocks, but the veins are mostly within the more competent gabbro host.

There are potentially economic deposits of talc within the ultramafic footwall block to the Deer Cove deposit. One of these outcrops can be seen along the road a few hundred metres south of the portal. It is easily recognized by the white colour of the outcrop.

Stop 6.5
The Stog'er Tight Gold Deposit

From the previous stops, return to Mings Bight road and drive south, then turn west on another road about 4.8 km before the junction with the La Scie highway. The mine site is signposted. The Stog’er Tight deposit was discovered in 1988 by Noranda and is the largest of several similar deposits in this small area. The unusual name is a reference to the Stog’er Tight Lounge in the community of Fleur-de-Lys, which was a popular watering hole for the Noranda geologists. The verb “stog” is one of many unique Newfoundland expressions, and it is defined by the Dictionary of Newfoundland English as “T*o fill the chinks in a log-house with moss; to insulate a house*”. In the authors’ experience it is applied to many situations in which someone or something becomes filled to capacity, for example marathon eating sessions (“scoffs”) or even completely blocked toilets.

Stog’er Tight was explored in the late 1980s and early 1990s, and the zone of alteration and mineralization was traced for 650 m along strike and down dip for about 150 m. The mineralization is locally high-grade, and a resource of 650,000 tonnes at 6.7 g/t Au was outlined during advanced exploration. The deposit was eventually brought into production by Ming Minerals in 1996 and 1997, but the venture proved unsustainable. The deposit proved to be a series of mineralized lenses within a larger shear zone, and mining efforts were thus complicated by unpredictable dilution problems. The geology of the gold deposit is discussed by Huard (1990), Ramezani (1992), Kirkwood and Dubé (1992) and Evans (2004). The following summary is derived from these sources.

Gold mineralization at Stog'er Tight is hosted by one of three gabbroic sills, which intrude a sequence of mafic volcanic and volcaniclastic rocks, of both arc-type and oceanic-island-type affinity. The host gabbro is dated precisely at ~ 483 Ma (Ramezani, 1992). Mineralization occurs within a broad envelope within which four discrete types of alteration show a consistent arrangement. The best mineralization is associated with red albite–pyrite alteration and replacement of the gabbro, which passes outward into chlorite–magnetite, ankerite–sericite and chlorite–calcite alteration. The highest grade red albite-pyrite zones form discontinuous lenses or veins, and the gold is associated with the pyrite. Gold forms microveinlets and blebs in the pyrite, and is only very rarely visible in hand specimen. Grades are variable, with some grab samples containing up to 115 g/t Au. Channel sampling in the early stages of exploration, and later diamond drilling returned grades between 2 g/t Au and 23 g/t Au over widths of 1 to 8 m. Detailed information concerning drill intersections is given by Evans (2004). Abundant quartz veins occur within the mineralized zones, and the strongest alteration and mineralization is typically adjacent to these. The altered mafic rocks at Stog'er Tight contain hydrothermal zircon, dated by Ramezani (1992) at ~ 420 Ma, which is inferred to be the age of the gold mineralization. Kirkwood and Dubé (1992) conducted a structural study of quartz veining and alteration which identified four main vein types; the veining associated with the gold was interpreted to be relatively early (D_1), and mineralized structures are affected by later events.

The features of the mineralization at Stog'er Tight are very well displayed in the open pit. ***BE CAREFUL WITHIN THE PIT, AS SOME STEEP FACES MAY BE UNSTABLE, AND IT MAY BE PARTLY FLOODED! THIS IS NOT A GOOD PLACE TO CLIMB ABOVE OTHER PARTICIPANTS!***

Relatively unaltered gabbroic host rocks are best observed on the south side of the pit. There are scattered quartz–albite stringers containing auriferous pyrite in this area. The highest-grade mineralization and most intense alteration is seen in the centre of the east wall of the pit, where a deeper, slot-like pit has been excavated to extract it. Several wide quartz–albite–pyrite zones are present in this area, and the gabbro is pervasively altered. Less altered gabbros, representing more distal alteration assemblages, are visible around this zone, which locally contains >30 g/t Au. Pyrite is locally abundant and spectacular. The mine tailings visible in the distance to the northwest mark the location of the former Advocate asbestos mine, north of Baie Verte.

Stop 6.6
The Pine Cove Gold Deposit

From the Stog'er Tight open pit, return to the main road, and turn northward, then take the left branch at the next junction. This road winds down toward the coast and ends at the Pine Cove gold deposit.

General Information

The Pine Cove deposit is located in the same general area as Goldenville, Deer Cove, Stog'er Tight and several other gold deposits visited on this excursion (Figure 3.5). The deposit is currently in a pre-production phase. Anaconda Gold Corporation conducted delineation drilling and feasibility studies over the last two years, and hope to commence mining operations in late 2005 or early 2006. The deposit has a long history of exploration, which is recounted in detail by Evans

(2004), and summarized here. The initial stages involved surficial geochemistry surveys and geophysics, which led to the discovery of gold-bearing quartz veins containing 6-10 g/t Au in 1988, by geologist and prospector Charlie Dearin. Subsequent drilling by Varna Resources and Corona Corporation defined two main gold prospects, which are termed the Thunder Zone and the Lightning Zone. The resource at the time was estimated at 2.75 million tonnes at 3 g/t Au, and the deposit was assessed for mining by NovaGold Resources in the early 1990s. Feasibility studies were positive, but the project did not proceed at the time due to other factors, notably the falling price of gold.

The property was eventually transferred to New Island Minerals Incorporated, who then optioned it to Anaconda Gold Corporation. Following two years of assessment work, bulk sampling, mill testing, and a positive feasibility study, Anaconda Gold announced a production decision in late 2004. The current resource total quoted by Anaconda Gold is 2.2 million tonnes at 2.9 g/t Au (indicated) with an additional 800,000 tonnes of inferred reource at slightly lower grades. The diluted reserves for open pit development are quoted at 1.87 million tonnes at 2.9 g/t (Anaconda Gold, press release, 2004). Anaconda Gold is also actively exploring around the deposit and at nearby zones (e.g., Romeo and Juliet, *see below*) in search of additional tonnage and potential high-grade zones.

Regional and Local Geology

The Pine Cove deposit is within the Point Rousse Ophiolite Complex (Figure 3.5), which comprised dismembered ophiolitic rocks, conformably overlain by mafic volcanic and volcaniclastic rocks (Hibbard, 1983; Figure 3.6). The geology in, and around, the Pine Cove deposit is described by Hibbard (1983) and Evans (2004). The latter account is based to a large extent on unpublished assessment and consultant reports, and forms the basis for the following summary.

In the vicinity of the deposit, the Point Rousse Ophiolite Complex is dominated by mafic flows and tuffs, which are intruded by gabbro and diabase. Gabbroic rocks are typically fine-grained, and are locally strongly altered, to the point where they can be hard to recognize. The dominant host rock at Pine Cove is inferred to have been gabbro (*see below*). The Pine Cove deposit lies close to the Scrape Thrust (*see* earlier stops), along which the Point Rousse Complex has been thrust southward over the mafic volcanic rocks of the Pacquet Harbour Group (Figures 3.5 and 3.6). The Pacquet Harbour Group in this area is polydeformed, and metamorphosed to amphibolite facies; it is also possibly structurally imbricated with the Point Rousse Complex along, and beneath, the main thrust plane (Hibbard, 1983). A related structure, called the Pasture Pond thrust, lies north of the deposit and structurally above it.

Gold Mineralization

The Pine Cove deposit belongs to the carbonate–quartz–sulphide replacement subclass of Evans (2004) and contrasts with the red albite–carbonate–pyrite replacement subclass exemplified by Stog’er Tight (*see* previous stop). The following description of gold mineralization is summarized from Evans (2004), in part compiled from unpublished assessment reports.

The Thunder Zone and the Lightning Zone are each hosted by a variety of rock types, including gabbro, mafic volcanics and hematitic volcanogenic arenites, and mineralization is confined to a structural slice between the Scrape Thrust and the Pasture Pond Thrust (Figure 3.6). The rocks are structurally complex and four phases of deformation were identified by Calon and Weicke (1990). Early deformation is largely responsible for the distribution of rock units, which reflect reclined tight to isoclinal folds. These early structures are affected by later deformation, which appears to be related to the southward emplacement of the Point Rousse Ophiolite Complex over the Pacquet Harbour Group, likely during the Silurian. The

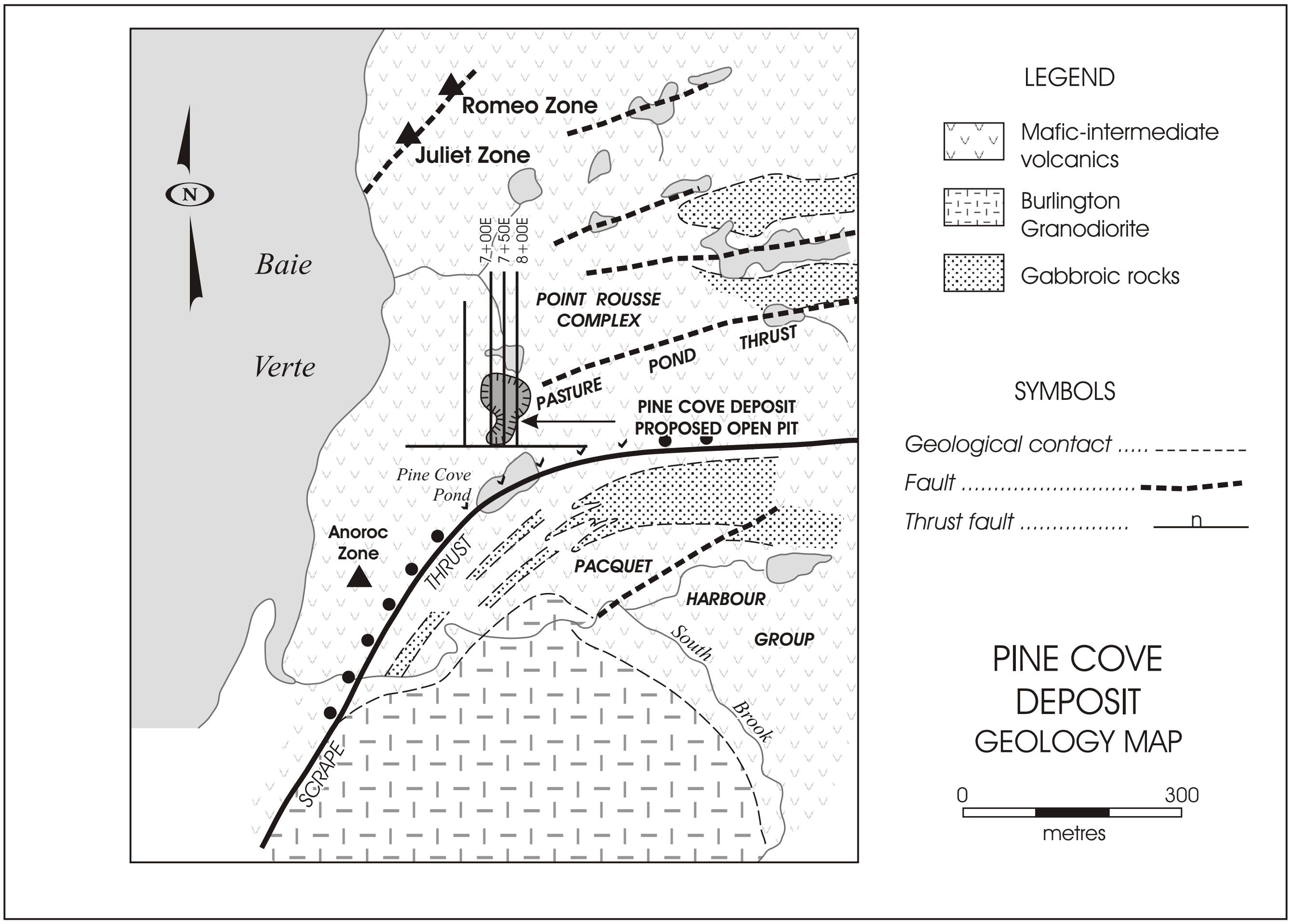


Figure 3.6. *Local geological map of the Pine cove area. From Evans (2004).*

gold mineralization occurs in two forms, i.e., in quartz veins and quartz–breccia zones that contain pyrite, and as disseminated auriferous pyrite in strongly altered wall rocks. The gold mineralization appears to be associated with the later (D_3) phase of deformation, with vein-style mineralization focused in the more competent (brittle) host rocks or in particular structural regimes, and disseminated mineralization focused in areas where permeability developed during D_3 deformation (Calon and Weicke, 1990). The predominant host for economic mineralization appears to be an intensely altered gabbro sill, now completely altered to iron carbonate, albite and pyrite. Duncan and Graves (1992) believed that the primary controls on the distribution of mineralization were lithological, rather than structural, and that most mineralization actually predated the D_3 event linked to southward thrusting.

The gold is associated with pyrite, which occurs in quartz veins, marginal to quartz veins, and as disseminated material. Gold occurs as inclusions and fracture systems grains in the sulphides, and gold grains are small, typically 1 to 50 microns in size. The grades reported from the deposit range up to 11 g/t Au over 8 m, and 10 g/t Au over 36 m, but gold values in the 2 to 6 g/t Au range are more typical on a deposit-wide scale (Evans, 2004; Anaconda Gold, press releases, 2004).

Description of Field Trip Stops

Until recently, there was relatively little to see on the surface at Pine Cove, and the surface exposures were badly overgrown. Recent development and trenching for bulk sampling by Anaconda Gold has created some interesting new exposures, which will be examined. The field trip will also include examination of recent drill core from the delineation phase of the project. Full details of this, and an outline of recent geological work, will be provided separately, courtesy of Anaconda Gold Corporation.

Stop 6.7
The Romeo and Juliet Prospect

The Romeo and Juliet prospect is located about 1.7 km north of the Pine Cove deposit (*see* previous stop) and is not accessible by vehicle (aside from the all-terrain variety). From the Pine Cove deposit, return along the access road for about 500 m to a small crossroads. From here walk northward on a logging trail for about 1.5 km; the trail is reasonably easy to follow, but parts of it may be rather muddy and treacherous. The trail eventually descends steeply toward the ocean, and the massive white quartz veins of the prospect are easily seen close to the end of the trail.

The Romeo and Juliet prospect was discovered in 1987 by Varna Resources. The veins were trenched, and four drillholes were completed, but the overall grades obtained were low, averaging about 2 g/t Au. However, bulk sampling in 1997 yielded 10 ounces of gold from a total tonnage of approximately 10 tonnes (MacNeil, quoted *in* Meade *et al.* (2001)), so these early estimates were clearly unrepresentative. Free gold is locally abundant, so these ounce-per-tonne results are not surprising. The veins are currently under further evaluation as part of the Anaconda Gold project. The geology of the prospect is described in detail by Meade *et al.* (1998, 2001) and by Evans (2004), and the following summary is based on these sources.

Mineralization at Romeo and Juliet is hosted by white quartz veins within relatively well-preserved variolitic pillow lavas and fine-grained gabbro of the Point Rousse Ophiolite Complex (Figure 3.5). It is an example of the quartz–gold vein subclass of Evans (2004). There are actually three subparallel quartz veins, which are exposed over a strike length of some 250 m. The veins are composite, and consist of numerous generations of parallel, milky-white quartz. Crack and seal textures, comb textures, laminated intervein selvages and altered wall-rock fragments attest to the complex history of vein emplacement. Sulphides are uncommon in the veins and most of the gold is free, typically developed as clots along vein margins and interfaces between individual vein generations. The irregular grade distribution makes it difficult to obtain reliable assay data from drilling or channel sampling, but the bulk sampling results (essentially 1 ounce per tonne) indicates that there is significant potential here for a small, high-grade resource.

Stop 6.8
The Dorset Prospect

From the previous stops on the Mings Bight peninsula, return to the La Scie Highway, and turn west, towards Baie Verte. Continue to a point approximately 0.5 km west of the bridge over Southwest Brook, where there is a small electricity substation adjacent to Southwest Brook. The location is about 1.6 km east of the junction of the La Scie and Baie Verte highways. Walk along the fence on the west side of the substation, and the prospect is located about 50 m north of the substation.

The Dorset prospect is described by MacDougal and McInnis (1990), Dubé and Lauziere (1992) and Evans (2004). The following description is based on these sources. Mineralization was initially discovered by Noranda during regional heavy-mineral sampling using stream sediments. The prospect was trenched, and tested with 10 short drillholes. The veins at the Dorset prospect are examples of base-metal rich auriferous quartz veins, but there have been some local spectacular concentrations of free gold, as shown in the frontispiece for the field trip guide. The prospect is hosted by mafic flows, pillow lavas and pillow breccias of the Flatwater Pond Group, which are intruded by numerous fine-grained mafic sills and dykes. There are 3 subparallel quartz vein systems located within shear zones. The veins contain pyrite, galena, chalcopyrite and bornite, associated with minor arsenopyrite and sphalerite. Locally, veins contain up to 10% sulphides. The shear zones that host the veins were interpreted to be early structures by Dubé and Lauziere (1992), who suggested that quartz veining was localized in the hinge zones of fold structures.

Samples like the one illustrated in the frontispiece might still be available if you look hard enough and we have enough time. However, time may be limited, as we have to drive to Pollards Point in White Bay, which will take close to 2 hours, even though it is only about 50 km as the crow flies!

DAY 7: MESOTHERMAL AND "CARLIN-LIKE" (?) GOLD MINERALIZATION IN THE HUMBER ZONE

Leaders: A. Kerr and Kermode Resources Staff

The final day of the field trip will examine different styles of gold mineralization in the eastern part of the Humber Zone, in the area on the western side of White Bay (Figure 3.7). Gold mineralization in this area occurs in Precambrian granites, Cambro-Ordovician sedimentary rocks and in Silurian volcanic and sedimentary rocks.

Geological Background

Western White Bay contains rocks that range in age from Proterozoic to Carboniferous (Figure 3.7). The regional geology is summarized by Smyth and Schillereff (1982) and by Kerr and Knight (2004), from which the following summary is condensed.

The area lies along the eastern edge of the Precambrian Long Range Inlier, which includes granitoid gneisses (~ 1500 Ma in age), intruded by granitoid rocks of 1030 - 980 Ma age, and late Precambrian (~ 615 Ma) diabase dykes. These Precambrian rocks are bounded to the east and unconformably overlain by a narrow belt of Cambro-Ordovician sedimentary rocks consisting of a lower clastic sequence overlain by dolostones and limestones. The Cambro-Ordovician sedimentary sequence includes most of the formations recognized in the undeformed platformal succession along the Gulf of St. Lawrence, but the belt is structurally complex (Kerr and Knight, 2004). The Precambrian basement and its autochthonous to parautochthonous cover rocks are bounded to the east by the *Doucers Valley fault system*, an important lineament that essentially divides western White Bay into two halves (Figure 3.7), and probably has a complex history of reactivation throughout the Paleozoic (e.g., Tuach, 1987). Cambro-Ordovician rocks east of the Doucers Valley fault system are considered to be part of a disrupted Taconic allochthon termed the Southern White Bay Allochthon (Smyth and Schillereff, 1982). The allochthon includes assorted clastic sedimentary rocks, metavolcanic rocks, minor ultramafic rocks and trondhjemites of the Coney Head Complex (Figure 3.7). Collectively, these rocks represent deeper water sedimentary facies and samples of oceanic crust transported westward across the ancient continental margin of North America. The eastern part of the area also includes the Silurian Sops Arm Group, consisting of mafic to felsic volcanic rocks, conglomerates and mostly clastic sedimentary rocks. The Sops Arm Group is considered to have been deposited unconformably on the Southern White Bay Allochthon, but this relationship is not easily demonstrated, as most contacts between the two are faults. The Sops Arm Group and all older rocks have been subjected to significant Silurian or post-Silurian deformation. Syn- to post-tectonic granitoid rocks of probable Silurian age are abundant in the south of the area, where they intrude the Sops Arm Group and older rocks (Figure 3.7). A similar granite that intrudes Precambrian basement west of Sops Arm (Devils Room Granite) has been dated at 425 Ma (Heaman *et al.*, 2002). Paleozoic diabase dykes (undated) cut Cambro-Ordovician carbonate rocks, but are not reported to cut the Sops Arm Group. The youngest rocks in the area are Carboniferous sedimentary rocks of the Anguille and Deer Lake groups (Figure 3.7), which unconformably overlie all Ordovician and Silurian rocks, including those of plutonic origin.

Excluding multiple Precambrian events recorded in gneisses of the Long Range Inlier, the area records at least three major orogenic events. The Ordovician Taconic Orogeny is believed to have involved emplacement of the Southern White Bay Allochthon over authochthonous Cambro-

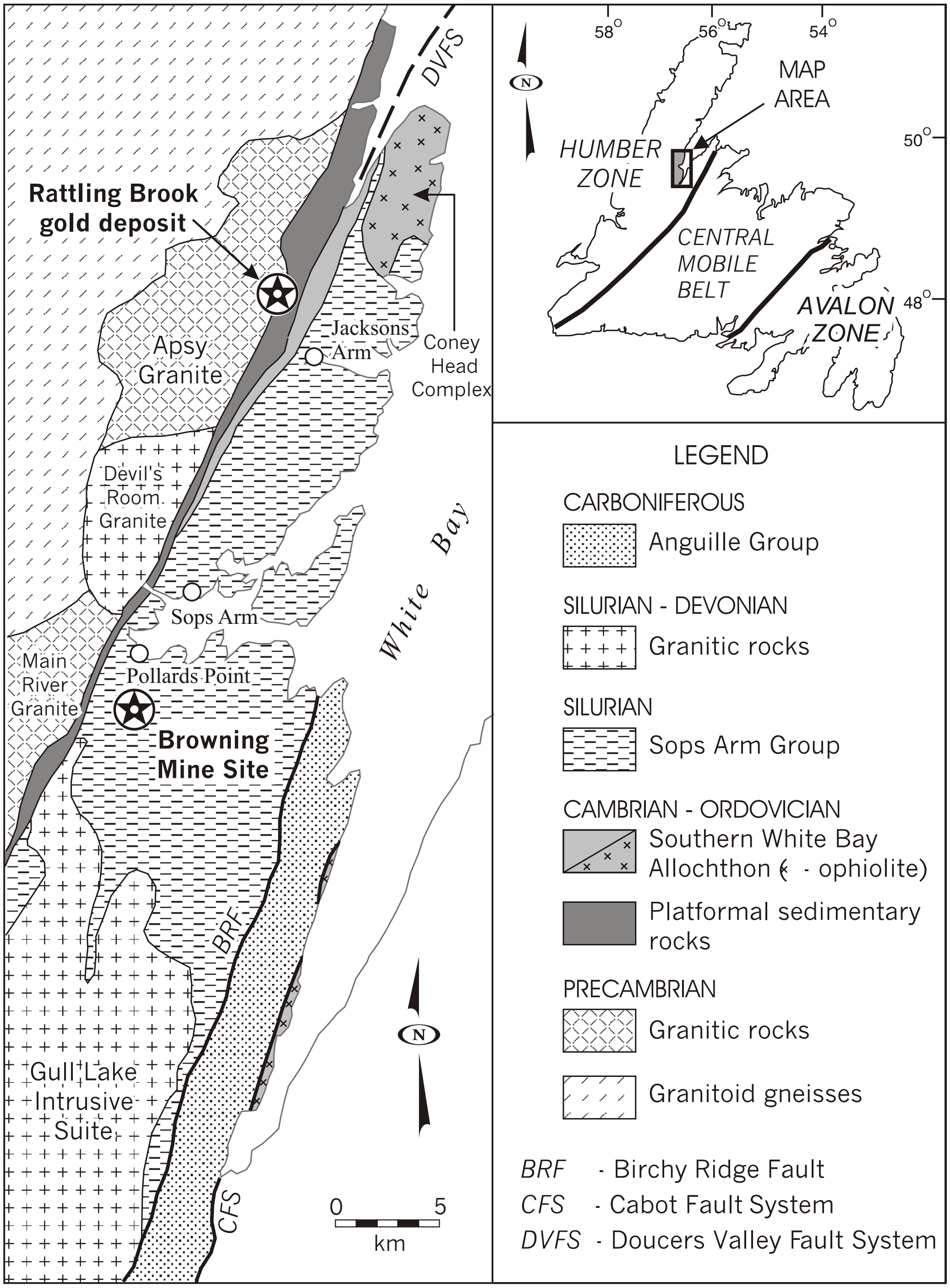


Figure 3.7. *Regional geology of the western White Bay area, after Smith and Schillereff (1982). Diagram modified after Kerr (2005).*

Ordovician rocks (Smyth and Schillereff, 1982; Kerr and Knight, 2004). The Silurian Salinic Orogeny and/or the Devonian Acadian Orogeny strongly affected Silurian and older rocks and probably created much of the present geological architecture. These events were accompanied and followed by granitic plutonism. Carboniferous or post-Carboniferous events (Variscan Orogeny) were also important, as rocks of the Anguille Group are tightly folded and older Silurian rocks have locally been thrust over the Carboniferous Deer Lake Group. Major lineaments such as the

Doucers Valley fault system are inferred to have been sites of significant strike-slip motion during Carboniferous and post-Carboniferous times, but these structures were likely established during earlier Paleozoic events (Tuach, 1987; Kerr and Knight, 2004). They may have a relationship to gold metallogeny, and to other types of mineralization known in this area.

Western White Bay contains a wide variety of metallic and nonmetallic mineral occurrences, and has a long (albeit sporadic) history of mineral exploration. The Silurian rocks of the Sops Arm Group contain most of the gold mineralization known prior to the 1980s; these consist of sulphide-bearing quartz–carbonate veins in either felsic volcanic or siliciclastic rocks. Disseminated gold mineralization was discovered in the early 1980s in Precambrian granitoid rocks, during construction of the access road for the Cat Arm hydroelectric project. Similar mineralization was later found in adjacent Cambrian sedimentary rocks. This area, now known as the *Rattling Brook gold deposit*, was extensively explored in the late 1980s, and is currently enjoying renewed exploration attention. In addition to gold, Pb and Zn mineralization occurs in thin carbonate units within volcanic rocks of the Sops Arm Group, and is generally considered to be of Carboniferous age (Saunders, 1991; Kerr *et al.*, 2004). Minor Cu–Ag mineralization is also present in Carboniferous sandstones (Tuach and French, 1986; Saunders, 1991), and fluorite, molybdenite and galena occurrences are reported from plutonic rocks (Saunders, 1991).

Gold mineralization in western White Bay occurs in several different settings, in rocks that range in age from Precambrian to Silurian. There is no guarantee that all of these occurrences formed during a single event, although such an interpretation is clearly permissible. Vein-hosted Au mineralization in the Sops Arm Group must be of Silurian or younger age, but several different possibilities exist for the Rattling Brook gold deposit, which was considered Precambrian until the discovery of gold in adjacent Cambro-Ordovician rocks (Tuach and French, 1986). The prevailing view of the last 15 years is that mineralization at Rattling Brook is of Paleozoic age, and possibly related to hydrothermal systems driven by Silurian plutonic complexes, but definitive proof of a link is lacking.

There have been several previous field trips to the western White Bay area over the years. Tuach (1987) provided the first comprehensive guide, later adapted to focus on the gold mineralization. The stop descriptions below are simplified from a more recent and comprehensive guide prepared by Kerr *et al.* (2004) as part of a GAC Newfoundland Section field trip.

The Rattling Brook Gold Deposit – An Overview

In the early 1980s, prospector Clyde Childs discovered auriferous gossans in Precambrian granites along the Cat Arm hydro access road. Almost ten years later, similar mineralization was discovered in the unconformably overlying quartzites and carbonate rocks. This extensive zone of disseminated Au mineralization, termed the Rattling Brook gold deposit, is the most important occurrence in the area in terms of total resources, and probably contains more than 1 million ounces of gold (C. Dearin, quoted by Kerr, 2005). The deposit is now attracting renewed attention, with current exploration focused largely in the sedimentary rocks, for which a Carlin-type exploration model has been proposed (e.g., Wilton, 2003). The mineralization in this area was described by Tuach (1987a, b), Saunders and Tuach (1988, 1991), Poole (1991) and, more recently, by Kerr (2004, 2005). The following account is summarized from these sources.

The Rattling Brook gold deposit contains four main zones (Figure 3.8). The *Road Zone* and *Incinerator Trail Zone* are hosted entirely by Precambrian Granite, whereas the *Beaver Dam Zone* is hosted almost entirely by Cambrian sedimentary

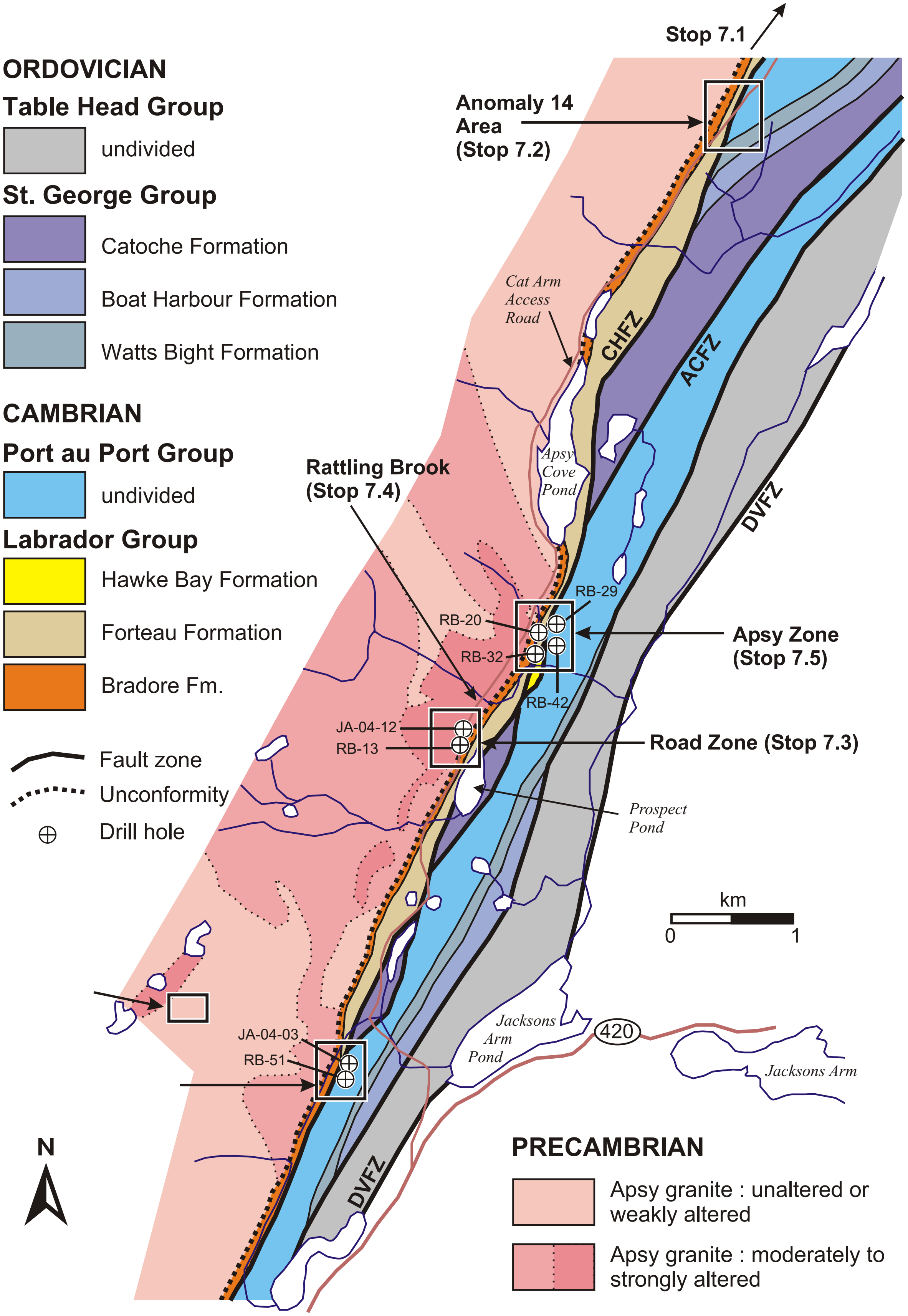


Figure 3.8. *Geology of the Rattling Brook gold deposit and surrounding area, western White Bay. Modified after Kerr (2005).*

rocks. The *Apsy Zone* is hosted by both granites and adjacent sedimentary rocks, and mineralization is continuous across the unconformity that separates them. Most previous descriptions of mineralization emphasize the granitoid-hosted environment. Recent work has emphasized sedimentary-rock-hosted mineralization in the Apsy and Beaver Dam zones (Kerr, 2004, 2005)

The granitoid-hosted mineralization is similar in all areas. It is dominated by disseminated pyrite and minor arsenopyrite, associated with a complex network of tiny fractures and thin veinlets that also contain quartz and Fe-carbonate. It is, in many respects, more like “porphyry-style” mineralization, and discrete megascopic mineralized veins (typical of most mesothermal gold deposits) are conspicuously absent. Typical mineralization contains only a few percent dispersed sulphides. Mineralization also occurs in “pretectonic” mafic dykes that cut the granites; these are considered to be ~ 615 Ma Long Range dykes. The mineralized dykes are strongly sericitized and pyritized, and appear superficially felsic where strongly altered. The general range of grades is only 0.5 to 2 g/t Au, with local enrichment up to 4 - 6 g/t Au, notably where dykes are present. These low average gold grades represent the most significant obstacle to further exploration and development. Saunders and Tuach (1988, 1991) linked physical and mineralogical changes in the host rocks to geochemical patterns, and established the timing of alteration events. They demonstrated that intense potassic alteration of the original granodiorites is an early large-scale metasomatic event, which is generally not associated with significant Au enrichment where present alone. This regional alteration is them overprinted by more localized effects, notably Na-metasomatism and/or silicification, spatially associated with the auriferous vein and fracture systems. The sulphides are mostly pyrite and arsenopyrite, with minor pyrrhotite, galena, chalcopyrite and tennantite. Gold was observed only very rarely, as clusters of small grains ranging from <1 m to around 15 m in diameter, generally bound within pyrite. It is not known if “invisible” (refractory) gold is present in the pyrite or arsenopyrite, but metallurgical test results reported by BP-Selco in the late 1980s suggest that this is possible. Diabase dykes of presumed Paleozoic age cut the mineralized zones and appear unaltered and unmineralized; however, they also remained undated, and do not (yet) provide any age constraints.

Mineralization in Cambrian sedimentary rocks is close to the sub-Cambrian unconformity, and generally localized between this zone and major faults that define the structural base of grey to buff dolostones, assigned to the Cambrian Port au Port Group (Figure 3.8). Locally, grey limestones of probable Ordovician age form the hanging wall; these are probably tectonic lozenges caught within the fault zones. The distribution of gold mineralization in sedimentary rocks at the Beaver Dam and Apsy zones is not strictly controlled by stratigraphy or rock type (Kerr, 2004). It is present in the Forteau Formation carbonate rocks, Bradore Formation quartzites, and also within altered granite beneath the unconformity at the Apsy Zone. However, there is some stratigraphic influence, because the strongest Au enrichment is generally within the calcareous, magnetite-rich rocks that occur at the transition between the Bradore and Forteau formations. The highest gold assays commonly correspond with “calcareous ironstones”, in which magnetite is variably replaced by pyrite. There is a strong correlation between gold and arsenic, and arsenic profiles are essentially identical in shape to the gold profiles (Kerr, 2004, 2005). However, high As values are locally present in the upper dolostones, accompanied by only trivial Au enrichment. Arsenic is thus a fellow traveller with Au, but not necessarily a pathfinder on a local scale. Important geochemical features of the mineralization were summarized by Kerr (2005). These include high Au/Ag ratios, high Au/base-metal ratios, and enrichment in As, W and Sb. Evidence for silicification and decarbonatization in sedimentary-rock-hosted mineralization was also noted. Such features are compatible with models suggesting a Carlin-like environment, but not necessarily diagnostic of such.

In drill core, the auriferous zones are mostly characterized by fine-grained disseminated pyrite, and lesser crosscutting pyritic veinlets. Magnetite-rich rocks near the Bradore–Forteau formation boundary commonly show partial to complete replacement of magnetite by pyrite. Pyritic limestones are cut by silica veinlets, and may be partly silicified, but there is little or no sign of alteration in mineralized quartzites. A pink mineral observed in small crosscutting veinlets is suspected to be K-feldspar, and a soft, white "clay-like" alteration is locally evident in mineralized carbonate rocks. The grades of sediment-hosted gold mineralization are generally higher than those recorded from granite-hosted mineralization. For example, grab samples of pyritic quartzite from the Beaver Dam Zone contain up to 35 g/t Au. Drill intersections from BP-Selco work in the late 1980s include 3.5 m of 5.5 g/t Au, including 2 m of 7.5 g/t Au, and 2.1 m of 7.3 g/t Au (Poole, 1991). Previous results from the Apsy Zone include 2.5 g/t Au over 6.5 m, and 4.1 g/t Au over 3 m (Poole, 1991). Renewed drilling in both areas in 2003-04 produced similar intersections, with grades of over 10 g/t Au over narrow widths within them (Kermode Resources, press releases, 2004). Individual mineralized samples analyzed by Kerr (unpublished data) contain grades in excess of 16 g/t Au. Kermode Resources have also drilled some holes within sedimentary rocks outside the main area of mineralization, and some of these contain anomalous Au values (up to 0.5 g/t Au).

Stop 7.1
Precambrian–Cambrian Unconformity, Cat Arm Road

From Pollards Point, travel north on Route 420, toward Jacksons Arm. The road runs along the trace of the Doucers Valley fault zone, which here juxtaposes (probably) Ordovician carbonate rocks on the west, with a thin, attenuated sliver of the Southern White Bay Allochthon in the east. The high hills in the west are Precambrian basement rocks. Just before Jacksons Arm, the Cat Arm access road leaves Highway 420 by a blue shed. Follow the access road for approximately 12.4 km to a point just south of Little Coney Arm, just before a small power line crosses the road. The geology of the area to be visited, and the field stops, are indicated in Figure 3.8.

This outcrop is located on the west side of the road, and reveals the contact between ~ 1000 Ma old megacrystic granodiorite and quartzites of the Early Cambrian Bradore Formation. It is an excellent example of the basal unconformity, but here the underlying rocks are coarse-grained, K-feldspar megacrystic granodiorite of the Apsy Granite, rather than banded gneiss representing older components of the Long Range Inlier.

The southern part of the outcrop is granite, and the northern part is quartzite and conglomerate. The conglomerates are developed above the unconformity surface. One of the conglomerates has a clast population dominated by K-feldspar pebbles that are only marginally rounded, accompanied by blue-grey quartz. This arkosic rock is essentially a resedimented granite, suggesting very local derivation. Other clast types include massive quartz, and a purplish aphanitic rock that resembles a felsic volcanic. The Apsy Granite is the main host for gold mineralization to be visited later today.

Stop 7.2
Port au Port Group Dolostones, Calcareous Mylonites, Missing Stratigraphy

These outcrops are located approximately 2.0 km south of the previous Stop, at a long roadcut outcrop (Figure 3.8). The first part of the stop is back along the road; after visiting this, walk northward past the larger outcrops and a small quarry to outcrops located at the junction with a small road that leads to the power line. All of these outcrops are interpreted to be part of the Middle Cambrian

Port au Port Group, which is in fault contact with Bradore Formation quartzites. The Hawke Bay Formation and most of the Forteau Formation are missing here. These outcrops were also described by Tuach (1987a); the following is an augmented description.

A small outcrop on the west side of the road, about 200 m back, shows pale, beige-weathering dolostones containing numerous blue-grey quartz veins. In addition to the veining, the dolostone appears to be hard and silicified. This outcrop is considered by exploration companies to represent a partially formed "jasperoid", i.e., a silicified carbonate rock commonly associated with Carlin-style gold mineralization in the southwestern USA. Quartz veining is common in dolostones in the field trip area, reflecting their tendency toward brittle behaviour, but silicification of this type is rare. The main part of the roadcut outcrop consists of light grey to beige recrystallized dolostones, typically thickly bedded and featureless. A small outcrop of Bradore Formation quartzite occurs on the west side of the road, opposite the quarry. Several hundred metres of stratigraphy are missing across the fault that separates the two outcrops.

An outcrop of grey limestones just north of the road junction is a mylonitized grey limestone, which likely represent the lowermost limestone formation of the Port au Port Group, subjected to strong deformation. The "laminated" appearance of the outcrop is believed to record extreme stretching of burrows in the original limestones. A short distance up the side road, which leads to two Kermode Resources drill sites, are small outcrops that contain abundant minor structures. Some of these (overturned folds and small thrusts) indicate westward or northwestward transport, but others indicate later extensional motions. The side road ends on the power line, where massive dolostones outcrop around the drill sites. The two holes completed at this site represent the most northerly point at which the sedimentary rocks have been tested for mineralization. Neither hole contained high-grade mineralization, but both contained anomalous gold (up to 0.5 ppm Au) in calcareous phyllites structurally above the quartzites. The stratigraphy remains untested between here and the Apsy Zone (*see* later stops), a distance of about 4 km.

Stop 7.3
Road Zone Gold Prospect

From the previous stop, continue southward. The road crosses into basement rocks of the Precambrian Long Range Inlier. Stop 7.3 is located just south of the turning for a small auxiliary generating station located about 500 m south of the bridge over Rattling Brook (Figure 3.8).

The Road Zone represents the original discovery outcrop for the gold mineralization. It is a fairly small outcrop, and climbing it is not recommended. Loose blocks demonstrate the typical appearance of auriferous granites, which contain widespread disseminated pyrite. The pyrite is locally visibly associated with grey siliceous veinlets, but the latter are not always evident in hand samples. Arsenopyrite is present, but is generally fine-grained and difficult to identify. The most strongly altered and pyritized granites are greyish in colour and appear fine-grained. White quartz veins cut the outcrop, but do not appear to contain mineralization. Just north of the Road Zone outcrops is another outcrop that contains foliated amphibolites, which probably represent late Precambrian Long Range dykes. A marked cataclastic fabric is developed in the granite, and appears to be parallel to the dyke contacts in some areas. This fabric, and the foliation in the amphibolites, probably records Paleozoic deformation. The site of drillhole JA-04-12, (to be examined later) is located slightly to the north of here, and the amphibolites are probably equivalent to the mineralized dykes noted in the core. However, there is no evidence of mineralization in the surface outcrop. The 1 km traverse from this outcrop to the Apsy Zone is described in detail by Kerr *et al.* (2004); only the "highlights" are reported here.

Stop 7.4
Mineralized Granites and Potassic Alteration

This stop is located about 400 m north of the previous stop, just south of the bridge over Rattling Brook (Figure 3.8). This is a large outcrop of mineralized granite that contains abundant pyrite, much of it associated with a network of cross-cutting siliceous veinlets. Locally, where such veining is intense, the rock resembles a "tuffisite" in that the host granite appears brecciated; however, such textures do not necessarily indicate the actions of a gas phase. The outcrop also contains prominent white quartz veins. At the bridge over Rattling Brook, the granites are not mineralized, but they do show potassic alteration, and are cut by barren white quartz veins. North of the bridge, there is an amphibolitic unit, interpreted as a Long Range Dyke. The dyke contains some minor sulphide mineralization associated with crosscutting fractures, and is anomalous in Au. Potassic alteration of the granite can be seen easily in the outcrops, which are virtually syenitic in places; however, this is not the original composition of the host (Saunders and Tuach, 1988). The contacts between "normal" granite and the pink or red potassic varieties are locally sharp, but more commonly gradational. The alteration of the granite is discussed in detail by Saunders and Tuach (1988, 1991).

Stop 7.5
Apsy Zone Gold Prospect, and Post-Mineralization Diabase

This stop is located about 600 m north of the bridge over Rattling Brook (Figure 3.8). The Apsy Zone consists of a large outcrop on the west side of the road, and a much smaller outcrop on the east side of the road. The former outcrop is mineralized granite and the latter outcrop is mineralized quartzite. The granite-hosted mineralization was recognized and drilled in 1986. The mineralized quartzite was discovered later, after similar rocks were intersected by drilling. The mineralized granite outcrop on the west side of the road resembles those seen earlier in the traverse, but mineralization is more extensive and locally might even be described as "spectacular", depending on your frame of reference for such terms. The mineralized quartzite outcrop on the other side is certainly not spectacular, and much of the rusting superficially appears to be confined to fractures and joint faces. However, finely disseminated pyrite is present in the quartzite, and grab samples of this material contain about 1 g/t Au. Drilling shows that gold mineralization is actually hosted by altered granites, Bradore Formation quartzites and Forteau Formation basal carbonate rocks, and is locally continuous across the basal unconformity (Poole, 1991; Kerr, 2004).

About 200 m south of the Apsy Zone, on the west side of the road, there is an obvious fresh diabase dyke in a mineralized outcrop. This possesses chilled margins, and it has the ENE trend typical of other known Paleozoic dykes. Although the granites that surround it are rusty and pyritic, there is no sign of alteration or mineralization in the dyke, suggesting that it postdates the mineralization.

Gold Mineralization in the Sops Arm Group – An Overview

Vein-hosted gold mineralization has been known in the Silurian Sops Arm area for over a century. Most of the gold occurrences are located within the lowermost (mostly felsic) volcanic formation or the overlying siltstones and minor carbonates of the Simms Ridge Formation (Figure 3.7) There may be a spatial association of gold with the boundary between these units, which is believed to be a Silurian fault, possibly a thrust. The following summary is derived from Kerr *et al.* (2004), based in part on previous accounts, notably Saunders (1991).

The best-known deposit is the former Browning Mine, where gold mineralization is hosted by thin quartz–carbonate veins, which contained disseminated pyrite, chalcopyrite, sphalerite, and galena. The veins are hosted by calcareous sedimentary rocks of the Simms Ridge Formation, and appear to be localized above a shallow-dipping, schistose zone interpreted as a fault, possibly related to the nearby contact with the lower volcanic formation. The nature of alteration at this deposit is not entirely clear, but there is certainly evidence for the introduction of iron carbonate into the wall rocks. Other examples include quartz–carbonate (± feldspar)-dominated veins that cut a conglomeratic unit at the top of the Lower Volcanic Formation, or cut the pink rhyolitic flows lower in the stratigraphy. These examples seem to be associated with sericitic alteration. Saunders (1991) also reported auriferous quartz veins within the posttectonic Big Davis Pond granite of the Gull Lake Intrusive Suite, adjacent to its contact with the Sops Arm Group.

Stop 7.6
Felsic Volcanic Rocks, Sops Arm Group

This outcrop is located at the junction of Route 420 and the road leading to the town of Sops Arm, opposite the cleared area at the road junction, just north of the steel bridge over Main River (Figure 3.7). A long roadside outcrop exposes felsic volcanic and pyroclastic rocks; the best part is at the eastern end. The following is a modified description from Kerr *et al.* (2005).

The easternmost part of the outcrop is a massive, homogeneous, purple rock with small grey spots that may be relict phenocrysts or amygdules. This gives way westward to purple rhyolitic outcrops in which flow banding is well developed and spectacular. The western end of the outcrop is more heterogeneous, and includes well-preserved and spectacular fragmental rocks, considered to be of pyroclastic origin. The outcrop contains west-dipping quartz veins, and east-dipping schistose zones interpreted by Tuach (1987a) as minor thrusts. Buff zones of sericite and minor epidote are developed adjacent to some of the quartz veins. Tuach (1987a) considered these to be similar to marginal alteration associated with auriferous quartz veins elsewhere in the Sops Arm Group.

Stop 7.7
The Browning Gold Mine Area

The old Browning Mine is located a few km south of Pollards Point (Figure 3.7). Drive southward on Route 420 to the Pinksen’s forest resource road junction, and follow this road to the culvert over Corner Brook. There is a parking area on the east side of the brook, from which an old overgrown road heads southward. Walk up the old road for about 300 m to a clearing on the west side of the road. From here, descend the banks of Corner Brook to the original adit. ***THIS IS A STEEP DESCENT, BUT THERE ARE ENOUGH TREES TO PROVIDE HANDHOLDS. MAKE YOUR WAY DOWN SLOWLY, AND BE ESPECIALLY CAREFUL IN THE LOWERMOST SECTION, WHERE THE SURFACE IS LOCALLY VERY LOOSE AND GRAVELLY. IF WATER LEVELS ARE HIGH, THE VARIOUS OUTCROPS DESCRIBED BELOW CANNOT BE EXAMINED WITHOUT GETTING WET FEET. IF WATER LEVELS ARE VERY HIGH, THIS LOCALITY IS DANGEROUS AND SHOULD BE AVOIDED!***

Saunders (1991) provides a summary of the history of the deposit, and discusses many aspects of its geology. The description below is simplified from Kerr *et al.* (2004), and incorporates more recent observations..

The dominant rock types throughout the Browning Mine area are beige to pinkish, sericitized calcareous siltstones and sandstones of the Simms Ridge Formation. Corner Brook runs at a very slight angle to the strike of the beds, which dip moderately (20-40°) eastward. The waste dumps above the mine area, where shafts were once located, provide samples of vein quartz containing minor pyrite, chalcopyrite and galena; sphalerite and specular hematite. The adit is located above a prominent schistose zone at the base of the cliff, that can be traced both upstream and downstream. Quartz veins are also present in the schistose zone below the adit, where they are generally concordant with the fabric and locally appear to be folded. Very little information is available concerning grades during the period of active mining, but Saunders (1991) reports values of 4.8 to 7.2 g/t Au from various unpublished sources connected to later exploration and survey work.

Upstream from the adit, the siltstones and sandstones of the Simms Ridge Formation contain prominent brown spots, generally known as "siderite spots". There are also many flat boulders and slabs of pale brown to beige, variably dolomitic carbonate rocks. Surface patterns on some of these slabs show a honeycomb-like pattern that may indicate the presence of corals and/or bryozoa, and spiral shapes suggestive of gastropods have also been observed. The schistose zone eventually crosses the brook. Just beyond this, strongly deformed siltstones and sandstones contain small rootless isoclinal folds, that indicate a more complex structural history in this zone than one might at first think. About 75 m downstream from the adit, there is an outcrop that shows particularly intense quartz veining, in which the host rocks have been pervasively altered to brown iron carbonate-rich material. Downstream from here, there are numerous quartz-carbonate veins ranging from a few centimetres to 0.5 m in width. In many areas, brown iron-carbonate alteration haloes are developed around individual veins, but it is not clear if these actually overprint the siderite spots. The schistose zone that sits beneath the adit continues to crop out on the east bank of Corner Brook, and there are some prominent folds within this zone. The hinges of these folds plunge downdip, and they are locally overturned to the south, with a "Z" geometry; these folds are believed to record a later phase of motion than the "early" rootless folds noted in the upstream section. This phase of deformation may have been synchronous with vein emplacement. From this location, the road bridge over Corner Brook is accessible easily if water levels are low.

Stop 7.8
Sub-Carboniferous Unconformity

This outcrop is located on the west side of Route 420, approximately 17.3 km south of Pollards Point. ***WATCH FOR TRAFFIC! ALSO, BE VERY CAREFUL IN APPROACHING THE OUTCROP AS IT IS OVERHANGING AND LOCALLY UNSTABLE. FRESH FALLS OF LARGE BOULDERS HAVE BEEN NOTED ON MANY PREVIOUS VISITS TO THIS SITE!***

This spectacular outcrop that reveals the profound unconformity between the Silurian Sops Arm Group (north end of roadcut) and the Carboniferous Deer Lake Group (most of the roadcut). The latter are the youngest rocks examined on the field trip (excluding the Jurassic lamprophyre at Twillingate). Buff-coloured schistose rocks at the north end of the outcrop are interpreted as volcaniclastic rocks of felsic composition, which are interbedded with pale pink limestones. They belong to the lower volcanic formation of the Sops Arm Group. The rocks are tightly folded, and extensively crenulated; they are cut by small quartz–carbonate veins, and locally contain minor pyrite. At the unconformity surface itself, folding of these rocks has greatly reduced the angular discordance with the overlying boulder conglomerates. Reddening of the schists below the unconformity is interpreted to reflect Carboniferous groundwater circulation and related oxidation.

Above the unconformity are spectacular southwest-dipping boulder conglomerates and breccias, interpreted as debris-flow deposits. These are interbedded with red sandstones and finer grained conglomerates of probable fluvial origin. The boulder conglomerates are generally clast-supported, and are very poorly sorted. The most abundant clast types are mafic to felsic plutonic rocks that resemble local intrusive suites. Other clast types are felsic volcanics, schists and altered green fault-gouge like material. Although this is a very clear and obvious unconformity, there was some Carboniferous or younger deformation, because rocks of the Sops Arm Group have been thrust over similar Carboniferous conglomerates at a nearby outcrop.

This final outcrop illustrates some of the youngest Paleozoic rocks in Newfoundland, and demonstrates the importance of Silurian and Devonian (Salinic and Acadian) deformational events.

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