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NEW DEVELOPMENTS CONCERNING EPITHERMAL ALTERATION AND RELATED MINERALIZATION ALONG THE WESTERN MARGIN OF THE AVALON ZONE, NEWFOUNDLAND

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ABSTRACT

The development of both high- and low-sulphidation styles of epithermal mineralization, within late Neoproterozoic volcanic and associated sedimentary rocks in the western Avalon Zone of Newfoundland, demonstrates the unique preservation of this Precambrian epithermal environment. This region spans a distance of some 275 km and contains numerous occurrences of both high- and low-sulphidation-style gold mineralization. The recent recognition of potential porphyry-style mineralization within uplifted, or more deeply eroded, areas, coupled with the local preservation of possible sinter deposits related to low-sulphidation environments, demonstrates variable levels of preservation within these complex late Neoproterozoic porphyry–epithermal ore-forming systems.

Epithermal-related occurrences within the western Avalon Zone have been identified from the southern tip of the Burin Peninsula to the coastal areas of Bonavista Bay. The host rocks include the ca. *595–565 Ma Marystown Group, the* ca. *570–550 Ma Long Harbour Group, and the post-570 Ma sedimentary rocks of the Musgravetown Group. These volcanic successions and related sedimentary sequences, together with spatially associated high-level intrusion, document a protracted period of magmatic activity, related hydrothermal alteration, and local deposition of gold–silver mineralization.*

Recent and ongoing exploration within the region continues to identify new areas of mineralization, and thus provides new information to aid in the understanding of these late Neoproterozoic epithermal systems. In particular, new insights, provided by the application of visible/infrared spectroscopy (VIRS), allow for a better understanding of the mineralogy and spatial distribution of alteration zones surrounding these epithermal systems, which may assist in vectoring toward potentially economic mineralization.

INTRODUCTION

The Avalon Zone has long been recognized for its potential to host epithermal- and porphyry-related mineralization, in association with extensive zones of advanced argillic alteration, developed throughout the region (*e.g.,* Taylor *et al*., 1979; O'Brien *et al*., 1998). Extending from the Carolina Slate Belt in the south, to the Avalon Peninsula of Newfoundland in the north, the Avalon Zone represents the northeastern terminus of the eastern margin of the Appalachian orogen, which borders the eastern coast of North America (Williams, 1979; O'Brien *et al*., 1996, 1998). Historical gold producers within the Avalon Zone include the Hope Brook deposit in Newfoundland, and the Brewer deposit and correlatives in the Carolina Slate Belt (Scheetz, 1991; Dubé *et al.,* 1995; O'Brien *et al*., 1998, 1999; Ayuso *et al*., 2005). In addition to high-sulphidation systems, low-sulphidation systems of a similar age have also been identified in Newfoundland, where they locally display a close spatial association with identified high-sulphidation-style alteration (O'Brien *et al.*, 1998; Sparkes *et al*., 2005 and references therein). The close spatial association of these two types of epithermal systems is somewhat unusual because they have contrasting formational environments. High-sulphidation systems are characterized by highly acidic, oxidized hydrothermal fluids and are often associated with large alteration haloes (White and Hedenquist, 1995). In contrast, low-sulphidation systems are characterized by near-neutral, reduced hydrothermal fluids, due to the interaction with the adjacent wallrock, and have relatively restricted alteration haloes (White and Hedenquist, *op. cit.).* As a result, these systems can often be distinguished using the associated alteration and ore-forming minerals.

The western Avalon Zone of Newfoundland hosts numerous occurrences of high-sulphidation-style epithermal alteration and locally developed gold mineralization (*e.g.,* Dubé *et al*., 1995; O'Brien *et al*., 1998, 1999; Figure 1).

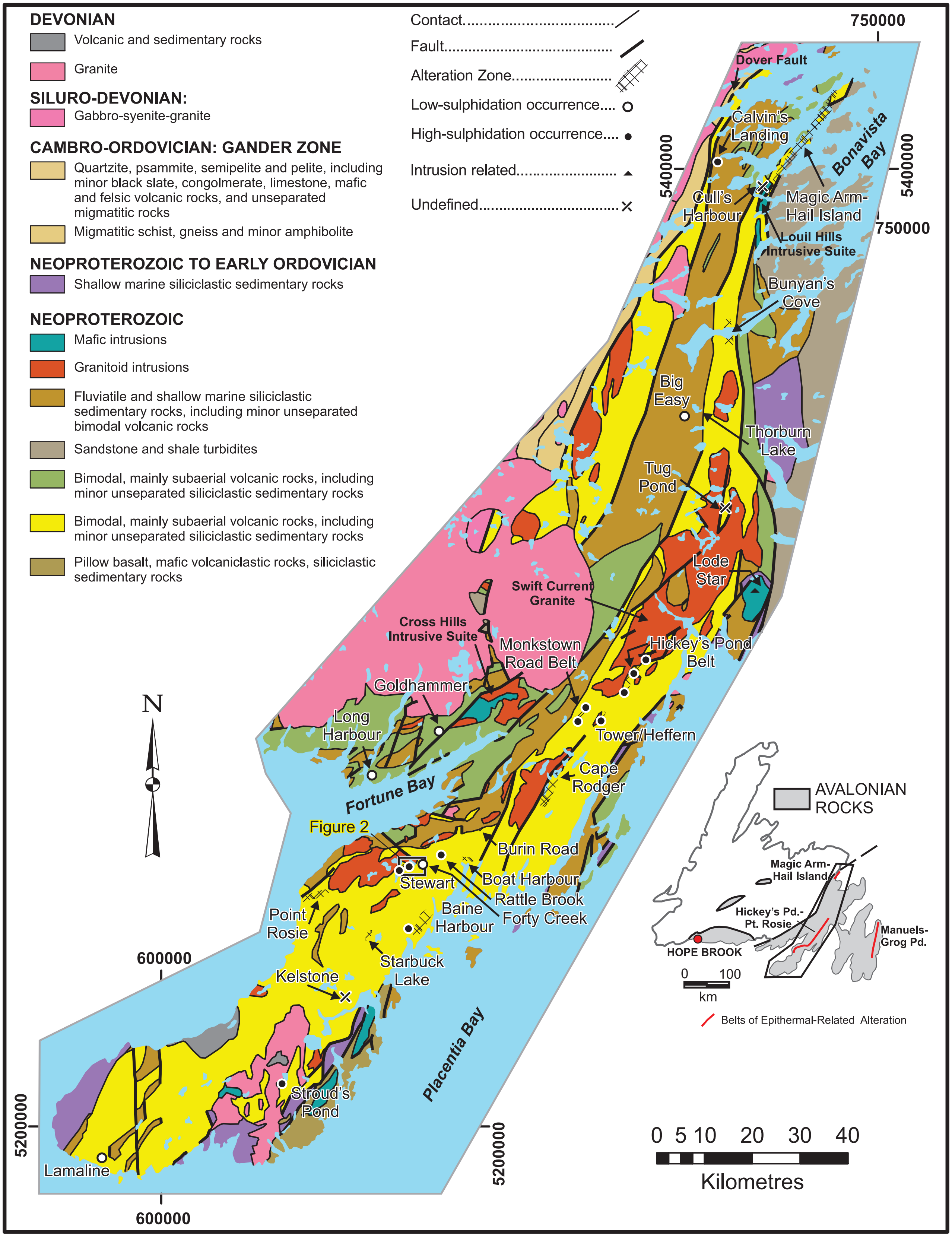

Figure 1. *Regional geology map of the western Avalon Zone outlining the distribution of known alteration zones and epithermal prospects (modified from O'Brien* et al.*, 1998; coordinates are listed in NAD 27, Zone 21).*

More recent discoveries of low-sulphidation-style chalcedonic silica veins highlight the potential for this style of mineralization within the western Avalon Zone (Seymour, 2006; Golden Dory website, 2011). Most of the epithermal alteration and mineralization identified in this region is hosted within subaerial felsic volcanic rocks ranging in age from 590–552 Ma. Recent exploration in the vicinity of the Big Easy prospect (Figure 1) has identified low-sulphidation mineralization hosted within sedimentary rocks of the Musgravetown Group. These represent some of the youngest host rocks in the region and demonstrate that the sedimentary succession immediately overlying the volcanic rocks is also prospective for gold.

Individual belts of alteration can be traced intermittently along strike for up to 16 km, throughout which variably developed alteration assemblages include quartz, pyrophyllite, alunite, muscovite, illite and locally diaspore. Significant mineralization, primarily consisting of gold but also containing silver, copper, arsenic and antimony, is locally present within these zones. This report provides an overview of some of the more recent epithermal-style discoveries throughout the western Avalon Zone and summarizes exploration highlights since the mid-2000s. It also provides information on initial field work in 2011, emphasizing the use of visible/ infrared spectroscopy (VIRS) as a tool in the investigation of alteration systems. This technique measures the absorption of the electromagnetic spectrum in the 350–2500 nm range using a TerraSpec® Pro spectrometer; the resultant spectra can be used to classify individual alteration minerals present within a sample. A more detailed summary of the procedure can be found in Kerr *et al*. (2011).

REGIONAL GEOLOGY OF THE WESTERN AVALON ZONE

The Avalon Zone of Newfoundland is dominated by late Neoproterozoic volcano-sedimentary rocks, punctuated by intermittent siliciclastic sedimentary sequences. This succession is, in turn, overlain by a Cambrian platformal sedimentary cover sequence that marks the cessation of volcanic activity and related epithermal systems within the Avalon Zone (O'Brien *et al*., 1996 and references therein). The Neoproterozoic rocks, along with the associated Paleozoic cover sequence, are unconformably overlain by Late Silurian to Early Devonian terrestrial volcanic and associated siliciclastic rocks, preserved within isolated outliers throughout the Burin Peninsula (O'Brien *et al*., 1995). The intensity of deformation broadly increases from east to west toward the Dover and Hermitage Bay faults, which mark the western extent of Avalonian rocks and define their tectonic contact with the adjacent Gander Zone (Widmer, 1950; Younce, 1970; Blackwood and Kennedy, 1975; Kennedy *et al*., 1982). Consequently, examples of epithermal alteration in the west are generally more strongly deformed than those located farther east on the Avalon Peninsula. Most of this deformation is developed during the Siluro-Devonian Acadian and Salinic orogenies (Dallmeyer *et al*., 1983; Dunning *et al*., 1990; O'Brien *et al*., 1991b, 1999; van Staal, 2007); however evidence for older deformational events are also locally preserved (*e.g.,* Anderson *et al.*, 1975; O'Brien, 2002).

Within the Burin Peninsula region of the western Avalon Zone, epithermal alteration zones are most abundant in volcanic rocks of the *ca.* 590–565 Ma Marystown Group (Strong *et al*., 1978a, b; O'Brien *et al*., 1999). This group generally comprises greenschist-facies subaerial flows and related volcaniclastic rocks ranging from basalt, through andesite and rhyodacite, to rhyolite; all of which display a calc-alkaline and tholeiitic affinity (Hussey, 1979; O'Brien *et al*., 1990, 1996, 1999). The Marystown Group represents the main core of the Burin Peninsula, forming a broad-scale anticlinorium, which is flanked to the east by a shoaling-upward sequence of marine to terrestrial volcano-sedimentary rocks of the Neoproterozoic Musgravetown Group (O'Brien, *et al*., 1999); volcanic rocks at the base of the Musgravetown Group have been locally dated at 570 +5/-3 Ma (O'Brien *et al*., 1989).

To the west and north, the Marystown Group is overlain by the *ca.* 570 to 550 Ma Long Harbour Group. The Long Harbour Group is dominated by shallow-marine sedimentary rocks and subaerial felsic volcanic rocks of an alkaline to peralkaline affinity, along with related clastic rocks, which pass conformably upward into fossiliferous Cambrian sedimentary rocks related to the development of a platformal cover sequence (Williams, 1971; O'Brien, *et al*., 1984, 1995). The Long Harbour Group is divisible into a lower volcanic sequence (Belle Bay Formation) and an upper volcanic sequence (Mooring Cove Formation), which are separated by a clastic sedimentary unit known as the Anderson's Cove Formation (O'Brien *et al*., 1984). Rhyolites from both the Belle Bay and Mooring Cove formations have been dated at 568 ± 5 and 552 ± 3 Ma, respectively (O'Brien *et al*., 1994).

North of the Burin Peninsula, the volcano-sedimentary sequence can be traced northeast to the area of Bonavista Bay (Figure 1), where the sequence pinches out along the Dover Fault (O'Brien, 1987; O'Brien and Knight, 1988). The volcano-sedimentary rocks within the area between the Burin Peninsula and Bonavista Bay are divisible into two broad northeast–southwest-trending belts, which are separated by sedimentary rocks of the Musgravetown Group. These belts include two different packages of volcanic rocks; the *ca.* 620 Ma Love Cove Group, which is confined to the eastern belt and a younger volcanic sequence inferred to be related to the *ca.* 570 Ma Musgravetown Group, which occurs within the western belt (O'Brien *et al*., 1992; O'Brien and Holdsworth, 1992). Both the eastern and western belts contain local evidence for epithermal mineralization (*i.e.,* Tug Pond, Calvin's Landing; Figure 1). Within the volcanic rocks of the Bonavista Bay area, numerous zones of silicification, pyritization and sericitization, in association with anomalous gold mineralization (up to 575 ppb Au) have been identified (O'Brien and Knight, 1988).

Several high-level plutons intrude along the western margin of the Avalon Zone. Most occur within the Burin Peninsula area and form a broad, semi-continuous, north-northeast-trending plutonic belt consisting of hornblende–biotite granite, diorite and gabbro (Figure 1). Limited geochronological data is available for these plutonic units, but the Swift Current Granite (Figure 1) was dated at 577 ± 3 Ma (O'Brien *et al.*, 1998). Other plutonic units, including the Cape Roger Mountain Granite and the Burin Knee Granite are inferred to be coeval with the Swift Current Granite (O'Brien and Taylor, 1983; O'Brien *et al*., 1984). At the northeastern end of the belt, in the vicinity of Bonavista Bay, the Louil Hills Intrusive Suite is dated at 572 +3/-2 Ma and is interpreted to be coeval with alkaline volcanism associated with the Musgravetown Group within the western belt of volcanic rocks (O'Brien, 1987, 1989). In the area northwest of the Burin Peninsula, the Long Harbour Group is locally intruded by the Cross Hills Intrusive Suite, which has a preliminary age of 547 +3/-6 Ma and hosts Zr–Nb rare-earth-element mineralization (Tuach, 1991). This intrusion represents one of the youngest magmatic events prior to the cessation of hydrothermal activity within the region.

HIGHLIGHTS OF RECENT ACTIVITIES WITHIN THE WESTERN AVALON ZONE

The similarities between the alteration observed within the Avalon Zone of Newfoundland and that developed within Avalonian rocks of the Carolina Slate Belt have long been recognized (*e.g.,* Taylor *et al*., 1979; O'Brien *et al*., 1998). The most intense mineral exploration in the western Avalon Zone was carried out following the discovery of the Hope Brook deposit in 1984; however, intermittent mineral exploration within this region commenced in the early 1900s with the investigation of hematite occurrences in the Hickey's Pond area. Epithermal-style mineralization was not recognized within the western Avalon region until the late 1970s (Hussey, 1978). As a result of the geological mapping conducted by both industry and government, several extensive zones of alteration were identified throughout the region (Figure 1). Many of these zones include variably developed advanced argillic alteration locally containing gold mineralization, and have been characterized as high-sulphidation epithermal-style mineralization (*e.g.,* O'Driscoll, 1984; Huard and O'Driscoll, 1985, 1986; O'Brien *et al*, 1998, 1999).

The most extensive mineral exploration conducted on the Burin Peninsula has focused on two main areas, namely the Hickey's Pond belt and the Stewart prospect (Figure 1). A detailed description of the Hickey's Pond belt and related mineralization is found in O'Brien *et al.* (1998, 1999) and it is only briefly summarized herein. This belt is characterized by highly sheared alunite, pyrophyllite, quartz, and specularite alteration hosting localized zones of vuggy silica and associated gold mineralization. Highlights from exploration within this area include channel samples of up to 12.4 g/t Au over 1.3 m (Dimmell *et al*., 1990), and drillhole intersections of up to 1.96 g/t Au over 3.1 m (Dimmell *et al*., 1993). Farther to the west, in the vicinity of the Monkstown Road belt (Figure 1), local grab samples have assayed up to 8.16 g/t Au within similar styles of alteration (Degagne and Robertson, 1985); however subsequent work within the area has yet to reproduce these results (Dimmell *et al*., 1991; Sexton *et al*., 2003). Cornerstone Resources conducted exploration in the Monkstown Road area in 2007, which included trenching of the adjacent Tower prospect (Figure 1); this work was successful in uncovering a significant zone of highly sheared advanced argillic alteration, which included pyrophyllite, alunite and locally topaz, but failed to identify any significant zones of gold mineralization (Dyke and Pratt, 2007).

The Stewart prospect is situated near the intrusive contact of a large composite high-level pluton consisting of hornblende–biotite granite with lesser felsite and quartz porphyry that intrude adjacent felsic volcanic rocks of the Marystown Group (O'Brien and Taylor, 1983). This area is characterized by an areal extensive curvilinear zone of advanced argillic alteration measuring up to 4 km long and up to 700 m wide (Figure 2). The alteration is hosted within tuffaceous volcanic rocks of the Marystown Group (Dimmell and MacGillivray, 1993; O'Brien *et al*., 1999). Within the prospect, this alteration is host to broad, low-grade mineralization that assays up to 0.25 g/t Au over 63 m; mineralization is associated with chalcopyrite, azurite, cuprite and molybdenite (Dimmell and MacGillivray, 1993). Narrower zones hosting anomalous copper mineralization are also developed within the advanced argillic alteration; examples of such include 0.28 g/t Au and 0.17% Cu over 4 m (drillhole NG-1; from 59–63 m), and 0.17 g/t Au and 0.1% Cu over 17 m (drillhole NG-2; from 141–158 m; Dimmell *et al*., 1990). A summary of the mineral exploration conducted on the Stewart prospect prior to 2000 can be found in O'Brien *et al*. (1999).

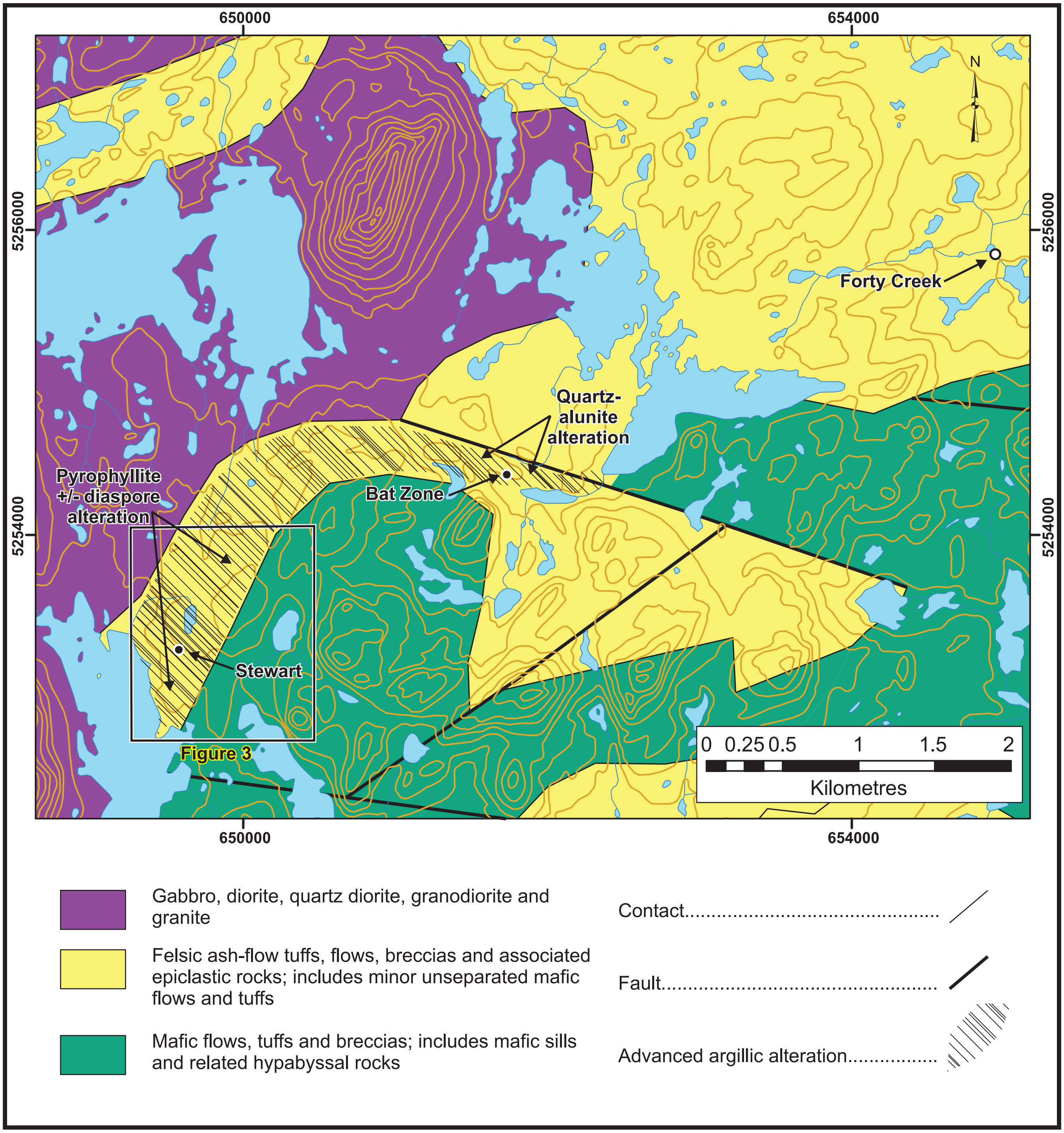

Figure 2. *Regional geology map of the area surrounding the Stewart prospect showing the distribution of advanced argillic alteration and location of related prospects (geological base map from O'Brien and Taylor, 1983; coordinates are listed in NAD 27, Zone 21).*

In 2007, Cornerstone Capital Resources Inc. carried out trenching and detailed mapping on the Stewart prospect. The trenching targeted an area approximately 600 m northeast of historical activity and identified additional zones of anomalous gold and copper mineralization that assayed up to 0.23 g/t Au, 0.05% Cu and 16 ppm Mo over 24 m (Dyke and Pratt, 2007). Additional excavation in the vicinity of historical trenching identified up to 0.55 g/t Au, 0.08% Cu and 48 ppm Mo over 12 m (Dyke and Pratt, *op. cit.*). Previous exploration within the area has largely focused on high-sulphidation related targets; however, as a result of the exploration work conducted by Cornerstone, the company identified the Stewart prospect as having the potential for porphyry-style mineralization (Dyke and Pratt, *op. cit.*) This realization was, in part, due to the trenching and detailed mapping conducted on the property, which identified the presence of a quartz-diorite intrusive unit. This unit is inferred to be the primary host to most of the mineralization within the prospect and is also host to the local development of a quartz stockwork zone hosting anomalous copper mineralization; however no follow-up drilling was conducted by the company. The Stewart prospect is currently being explored by TerraX Minerals Inc., who have conducted deeper drilling compared to previous exploration programs. The company is also testing geophysical anomalies identified by a Titan 24 survey carried out during the winter of 2010. Initial drill results from the vicinity of the northernmost trench assayed up to 0.13 g/t Au, 0.16 g/t Ag and 0.05% Cu over 111 m (TerraX Minerals Inc., Press Release, October 31, 2011). Additional drilling has been carried out with the aim of testing the alteration zone over a strike length of approximately 1.7 km.

The belt of prospective rocks that extends from the Burin Peninsula to Bonavista Bay has received much less attention with respect to gold exploration. The discovery of mineralized float containing high-sulphidation-style alteration at the Calvin's Landing prospect, in 2009, near Bonavista Bay, demonstrated the occurrence of high-sulphidation-style mineralization outside the Burin Peninsula region. The Calvin's Landing prospect consists of float containing up to 4.4 g/t Au in association with quartz–alunite–pyrophyllite–specularite alteration (Silver Spruce Resources, Press Release, June 16, 2009). This prospect represents the northern most occurrence of high-sulphidation-style alteration identified to date within the western Avalon Zone. Some limited exploration work targeting the volcanic rocks between the Burin Peninsula and Bonavista Bay was carried out by Minorex in the Tug Pond area in the early 1980s and by GT Exploration in Thorburn Lake area during the late 1990s. A government reconnaissance survey was also conducted over the southern portion of the western volcanic belt in the late 1990s. The survey failed to identify any significant mineralization, but did highlight several areas of alteration similar to that described on the Burin Peninsula (Reusch and O'Driscoll, 1987; O'Brien, *et al*., 1999).

In addition to the potential for high-sulphidation and porphyry-related mineralization within the western Avalon Zone, exploration has also identified occurrences of low-sulphidation-style mineralization, which previously had only been recognized within eastern portions of the Avalon Peninsula (Mills *et al*., 1999; O'Brien, 2002). Mineralization of this nature was first recognized in the western Avalon Zone in 2004 in the area of northern Fortune Bay (*i.e.,* Long Harbour prospect; Figure 1). In this area, crustiform–colloform-banded chalcedonic silica veins and associated cockade breccias, locally assaying up to 5.2 g/t Au and 3.8 g/t Ag, are hosted within volcanic rocks of the Long Harbour Group (Seymour, 2006; Crew and Seymour, 2007). More recently in 2008, prospecting carried out by Golden Dory Resources on the southern portion of the Burin Peninsula has led to the discovery of crustiform–colloform-banded chalcedonic silica veins hosted within an altered granite; these veins have returned assays of up to 1.2 g/t Au and 130.4 g/t Ag (Golden Dory Resources website). North of the Burin Peninsula, in the area of Thorburn Lake, Silver Spruce Resources has recently identified low-sulphidation-style textures such as crustiform–colloform-banded chalcedonic silica veins (*i.e.,* Big Easy prospect, *see* below) hosted by sedimentary rocks assigned to the Musgravetown Group (Silver Spruce Resources, Press Release, May 3, 2011).

PRELIMINARY INVESTIGATIONS IN 2011

BURIN PENINSULA REGION

In light of the recent exploration, the Stewart prospect was the focus of much work in 2011. This included detailed sampling for VIRS analyses to outline the distribution of the advanced argillic alteration on surface. This study was aided by detailed mapping conducted by previous exploration work in 2007, which identified a complex alteration assemblage developed marginal to, as well as within, a quartz-diorite intrusion (Dyke and Pratt, 2007). As a result of the work carried out by Cornerstone Resources, it was inferred that the Stewart prospect may represent a collapsed porphyry system, in which advanced argillic alteration was superimposed on underlying porphyry-style alteration and related mineralization (Dyke and Pratt, *op. cit.*). The current study covered an area approximately 1 km in length and up to 750 m wide. From this area, 63 samples were collected for VIRS analyses. Preliminary results of this investigation have outlined broad zones of illite- and pyrophyllite-dominated alteration, with the distribution of the later being largely coincident with the mapped distribution of the quartz-diorite intrusion. Due to the effects of the advanced argillic alteration and subsequent deformation, the identification of the primary host rock is not always easy. In addition to the surface sampling, two of the historical drillholes from the area were also analyzed in order to provide some insight into subsurface alteration. From these results four main alteration assemblages were identified: 1) pyrophyllite, 2) illite, 3) muscovite, and 4) illite-chlorite (Figure 3).

The western limit of the alteration within the Stewart prospect is marked by the contact with a high-level granite to granodiorite intrusion. This intrusion forms a portion of

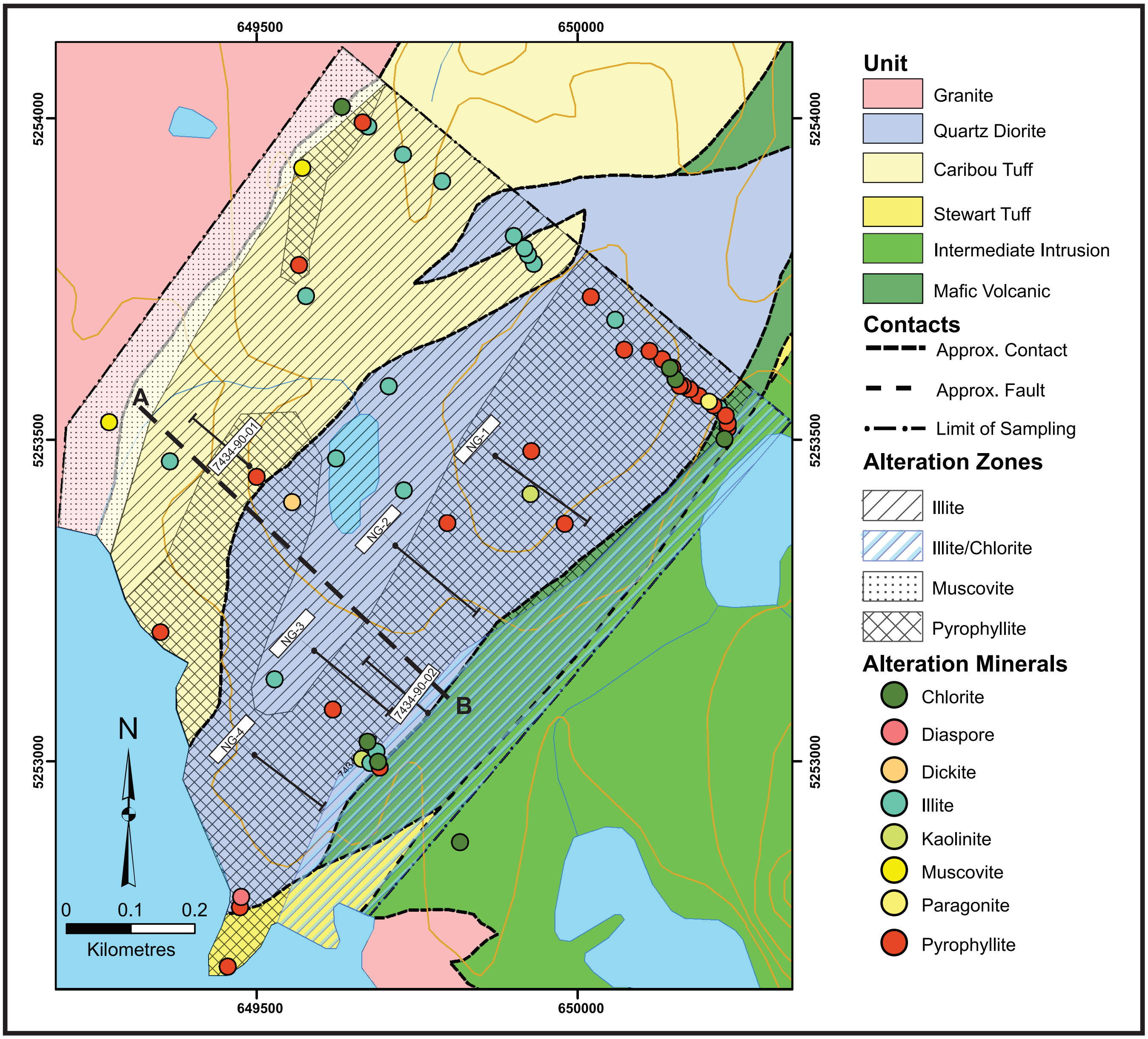

Figure 3. *Location map for samples collected for VIRS analysis as well as the dominant mineral in each; also shown is the interpreted aerial distribution of the four main alteration assemblages identified within the area and the location of historical drillholes (geological base map from Dyke and Pratt, 2007; coordinates are listed in NAD 27, Zone 21).*

the more regionally extensive Burin Knee Granite, which is interpreted to be coeval with the Swift Current Granite to the northeast (O'Brien and Taylor, 1983; O'Brien *et al.*, 1984, 1999). At the surface, the volcanic rocks immediately adjacent to the intrusion have undergone pervasive silicification. This silicification is locally crosscut by fracture-hosted pyrophyllite (Plate 1), indicating that the silicification predates the development of at least a portion of the advanced argillic alteration. Drillcore that penetrates the contact between the granite and the adjacent volcanic rocks displays similar alteration assemblages to those seen at surface. However, the drillcore also contains a 2 to 3 m zone of muscovite-dominated alteration developed within the outer margin of the granite (Plate 2). This implies that the intrusion predates the development of the hydrothermal alteration. Whether the silicification developed marginal to the intrusion of the granite is associated with the actual emplacement of the granite, or subsequent hydrothermal alteration focused along the contact, has yet to be determined.

Within the central core of the system, the main alteration assemblages are dominated by illite or pyrophyllite. The areal distribution of the pyrophyllite alteration largely corresponds with the mapped distribution of the quartz-dior-

Plate 1. *Silicified volcanic rocks crosscut by cm-scale vein of pyrophyllite marginal to the granite intrusion along the western edge of the Stewart prospect.*

Plate 2. *Muscovite dominated alteration developed within the outer 2–3 m margin of the granite intrusion located along the western edge of the Stewart prospect. Yellow arrow denotes the actual contact between the granite and the adjacent volcanic rocks (DDH 7434-90-01; Figure 3; width of core is 4.5 cm).*

ite intrusion, and there is no apparent spatial association with the adjacent high-level intrusion to the west. This suggests that there is no connection between the alteration and the high-level intrusion (Figure 3). Most drilling in the area, prior to that conducted by TerraX, has been relatively shallow with most holes terminating at less than 150 m vertical depth; this drilling indicates the alteration system remains open at depth (Figure 4). At surface, the alteration zone extends toward the northeast to the region of the Bat Zone, where the alteration grades into alunite-dominated alteration assemblages (Figure 2). The current distribution of the alteration within the area demonstrates that the highest-temperature mineral assemblages (pyrophyllite ± diaspore) are located toward the southwest, whereas quartz–alunite assemblages, which are more typical of a steam-heated environment (White and Hedenquist, 1995), occur mostly in the northeast. This is consistent with the moderate northeast plunge of the hydrothermal system inferred by TerraX Minerals (TerraX Minerals Inc., Press Release, July 19, 2011).

Trenching, conducted by Cornerstone, within the central portion of the alteration zone, uncovered localized rafts of less intensely altered quartz diorite that are enveloped by illite–pyrophyllite alteration (Plate 3). These rafts of 'less altered' quartz diorite are generally dominated by chlorite and lesser illite and are thought to represent a former zone of potassic alteration associated with deeper level porphyry-related alteration, which has undergone retrograde alteration to chlorite during metamorphism (Dyke and Pratt, 2007). The quartz-diorite unit is also locally host to cm-scale quartz veins, which are locally folded and boudinaged, and display variable orientations relative to the main foliation developed within the advanced argillic alteration. Similar veins were identified by Dyke and Pratt (2007) and were interpreted to represent hydrothermal quartz veins associated with porphyry-style mineralization and were noted to locally contain trace amounts of molybdenite and chalcopyrite.

The eastern limit of the alteration zone roughly corresponds with the contact of a mafic volcanic unit (Figure 3). It has yet to be determined if the chlorite within the illite–chlorite alteration along the eastern margin of the prospect is entirely of hydrothermal origin, or partly inherited from the primary mafic host rock, which displays regional chlorite–epidote alteration farther to the east.

Prospecting carried out by TerraX Minerals Inc. along strike from the Stewart prospect led to the discovery of bonanza-grade gold values at the Forty Creek prospect (Figure 2); located approximately 5 km northeast of the main Stewart prospect. At the Forty Creek prospect, localized outcrop and numerous mineralized boulders of quartz vein material contain up to 59 g/t Au and 2290 g/t Ag, along with anomalous Cu, Pb, Zn and Mo (TerraX Minerals Inc., Press Release, December 20, 2010). Mineralogical work commissioned by TerraX on the mineralized material has shown that the veins contain lead and silver tellurides, chalcopyrite and native gold (TerraX Minerals Inc., Press Release, July 19, 2011). Preliminary VIRS work indicates that associated cm-scale vugs infilled with white clay minerals, and intergrowths of similar clays with more massive quartz, are dominated by illite. The development of illite combined with the presence of telluride minerals is suggestive of a low-sulphidation environment (White and Hedenquist, 1995).

NORTHERN FORTUNE BAY REGION

Early indications of epithermal mineralization in the northern Fortune Bay region were first reported in 2004; with the identification of low-sulphidation-style crustiform–colloform-banded chalcedonic silica veins and associated cockade breccias within volcanic rocks of the Long Harbour

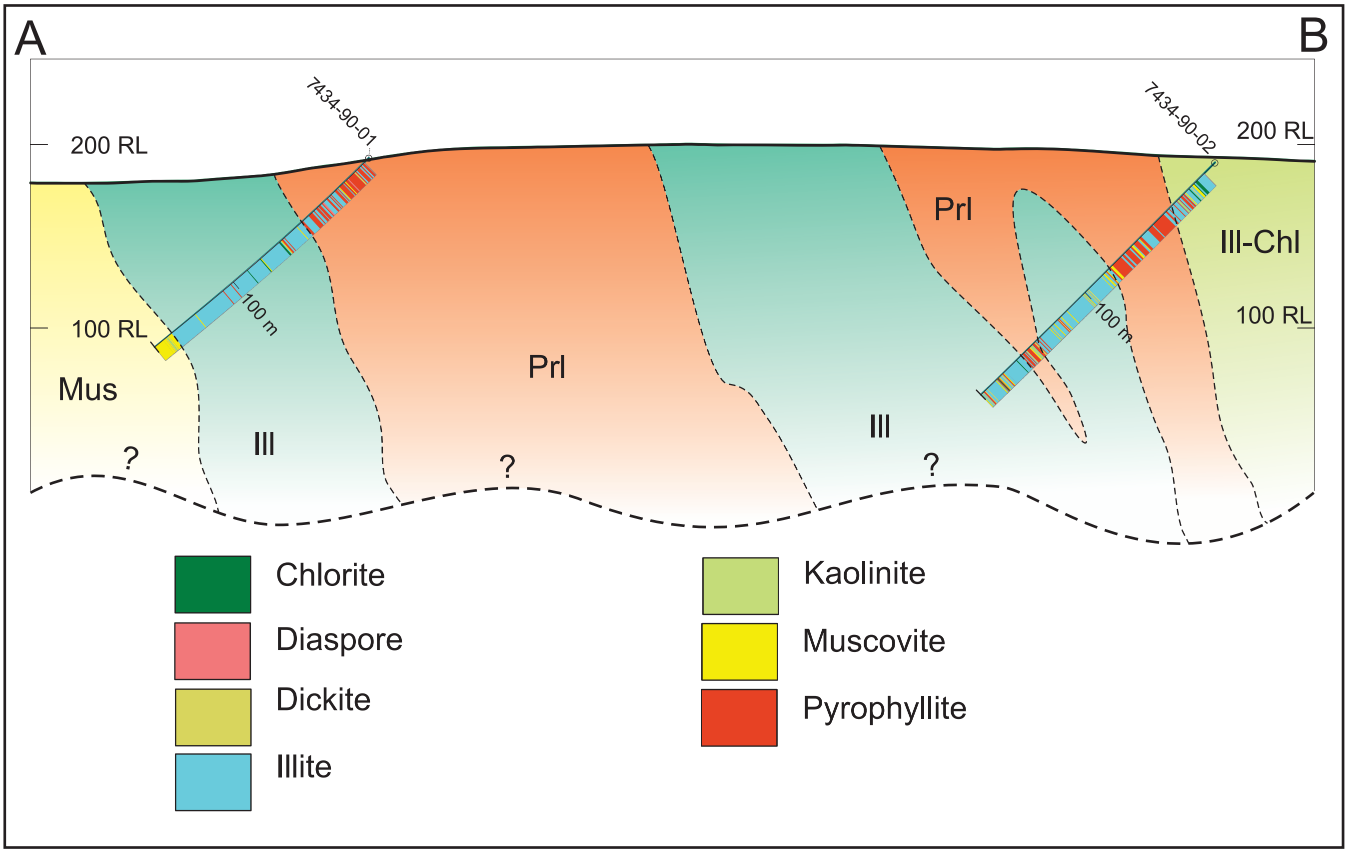

Figure 4. *Schematic cross-section outlining a simplified view of the subsurface distribution of hydrothermal alteration assemblages within the southern portion of the Stewart prospect. Striping within individual drillholes denotes a 0.5-m sample interval colour coded to the dominant mineral phase as outlined in legend. For the location of cross-section A–B refer to Figure 3.*

Plate 3. *Raft of relict chlorite-altered, medium-grained quartz diorite enveloped by rusty weathering, pyritic, illite–pyrophyllite advanced argillic alteration.*

Group (*e.g.,* Long Harbour; Figure 1; Seymour, 2004). Reconnaissance prospecting of anomalous selenium values in lake sediments have led to additional discoveries of gold mineralization farther to the northeast within similar volcanic rocks of the Long Harbour Group (*e.g.,* Goldhammer prospect; Figure 1; Hussey, 2006). The area of northern Fortune Bay has received very little gold-related exploration aside from some regional reconnaissance work from Inco Gold in the late 1980s, which targeted high-sulphidation-style mineralization following the discovery of the Hope Brook deposit, but failed to identify any significant mineralization (Bell, 1989). Most exploration targeted zones of pyritic alteration within the lower Belle Bay Formation of the Long Harbour Group, but this has proved unsuccessful. Although local occurrences of pyrophyllite–diaspore alteration (Plate 4) have been identified, indicating high-sulphidation-style alteration, no high-sulphidation-related mineralization has yet been discovered within the area.

The Goldhammer prospect, which locally contains up to 61 g/t Au in stockwork-style chalcedonic silica veins hosted within volcanic rocks of the Belle Bay Formation, represents a low-sulphidation epithermal style of mineralization (Hussey, 2006). Previous exploration in the vicinity of the Goldhammer prospect focused on the Cross Hills Intrusive Suite, which hosts anomalous uranium and rare-

Plate 4. *Well-developed pyrophyllite–diaspore advanced argillic alteration hosted within a primary volcaniclastic unit of the Mooring Cove Formation.*

Plate 5. *Crustiform-banded chalcedonic silica vein (yellow arrow) from the Goldhammer prospect. The $2 coin is 28 cm in diameter.*

earth-element mineralization (*e.g.,* Hopfengaertner, 1982; MacGillivray and Lechow, 1985; Churchill, 2001). Detailed sampling of the area has identified at least two generations of chalcedonic silica, with the later hosting most of the gold (Hussey, 2006). Chalcedonic silica veins and related stockwork zones locally display subtle, millimetre-scale banding (Plate 5), resembling crustiform banding as described by Dong *et al*. (1995). Locally, this crustiform banding is developed perpendicular to the adjacent wallrock (Plate 6); features such as this have been described from the Rodalquilar gold deposit in Spain, where they are interpreted to record the precipitation of amorphous silica in a near-surface environment (Arribas *et al*., 1995). Preliminary VIRS spectral analysis of the veining and adjacent wallrock identified illite and muscovite alteration as well as possible opaline silica. Ongoing mineralogical studies including staining and detailed petrography of the vein mineralogy are aimed at identifying key minerals, such as adularia, to fully confirm whether or not this area represents a true low-sulphidation environment.

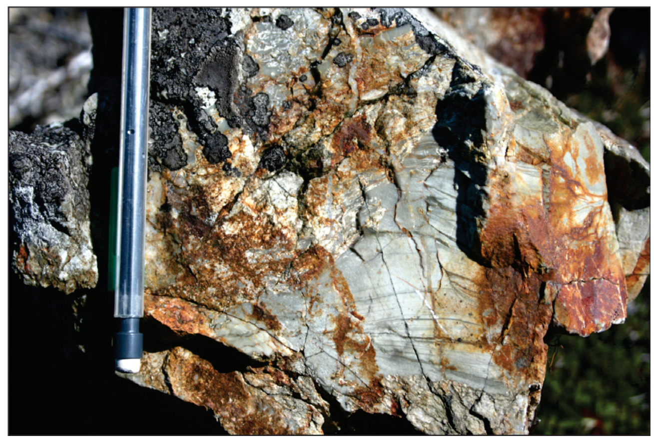

Plate 6. *Crustiform-banded chalcedonic silica vein from the Goldhammer prospect, displaying banding developed at high angles relative to the contact with the adjacent wallrock.*

THORBURN LAKE REGION

The area near Thorburn Lake was examined by GT Exploration Limited in the mid 1990s (Harris, 1996). Initial interest in the area was generated by an anomalous lake-sediment sample containing 10 ppb Au. Subsequent prospecting led to the discovery of a silica–pyrite alteration zone, which locally assayed up to 196 ppb Au, and measured up to 500 m in width and 1.8 km in length (Harris, 1996); however no further work was carried out on the prospect. More recently, Silver Spruce Resources resumed exploration and carried out trenching and diamond drilling, which led to the discovery of well-developed low-sulphidation-style chalcedonic silica veins and related brecciation (*i.e.,* Big Easy prospect; Silver Spruce Resources, Press Release, July 29, 2010). Trenching has also uncovered large blocks of layered chalcedonic silica material interpreted to represent potential sinter deposits (Silver Spruce Resources, Press Release, November 3, 2010). Subsequent drilling has now produced some of the highest grade gold intersections within low-sulphidation-style epithermal systems in the Avalon Zone of Newfoundland. The first phase of diamond drilling on the property has returned up to 0.87 g/t Au and 33.5 g/t Ag over 30.5 m, including 6.05 g/t Au and 174 g/t Ag over 1.5 m (DDH BE-11-3) as well as local intersections of up to 7.65 g/t Au and 10 g/t Ag over 1 m (DDH BE-11-7; Silver Spruce Resources, Press Release, May 3, 2011).

The host volcaniclastic sedimentary units at the Big Easy prospect are correlated with the late Neoproterozoic Musgravetown Group (Meyer *et al*., 1984). The area immediately north of the Big Easy prospect, in the vicinity of

Clode Sound, was mapped by O'Brien (1993). In this area, the Musgravetown Group is described as consisting of coarse-grained, mainly red, fluviatile clastic sedimentary rocks with locally developed basal conglomerate, overlain by a bimodal volcanic sequence. A rhyolite unit from the base of the Musgravetown Group has been dated at *ca.* 570 Ma and the sequence is locally unconformably overlain by Cambrian sedimentary rocks (Hayes, 1948; O'Brien, 1987; O'Brien *et al.*, 1989). Within the immediate area of the Big Easy prospect, the sedimentary rocks distal to the development of the silica–pyrite alteration consist of red, coarse-grained sandstone and lesser interbedded pebble to cobble conglomerate (Plate 7). The extensive silica–pyrite alteration at the prospect hinders recognition of the host rocks, but relict rounded sedimentary clasts were observed (Plate 8) suggesting that the host rock is similar to the surrounding sedimentary rocks observed marginal to the main alteration.

Plate 7. *Red to maroon, pebble to cobble conglomerate of the Musgravetown Group marginal to the pervasive silica–pyrite alteration developed throughout the Big Easy prospect.*

Veins measuring up to 50 cm in width, displaying typical low-sulphidation-style textures such as crustiform–colloform-banded chalcedonic silica are locally observed; some of which crosscut sedimentary layering at relatively high angle (Plate 8). In addition, large blocks (interpreted to represent subcrop) containing cm-scale layers of chalcedonic silica interlayered with coarse-grained sandstone are also present (Plate 9). Elsewhere, fragments of similar material form clasts within coarse conglomeratic units (Plate 10). These relationships suggest the formation and simultaneous erosion of epithermal sinter deposits during the deposition of the late Neoproterozoic Musgravetown Group.

BONAVISTA BAY REGION

In 2008, local prospectors discovered auriferous float

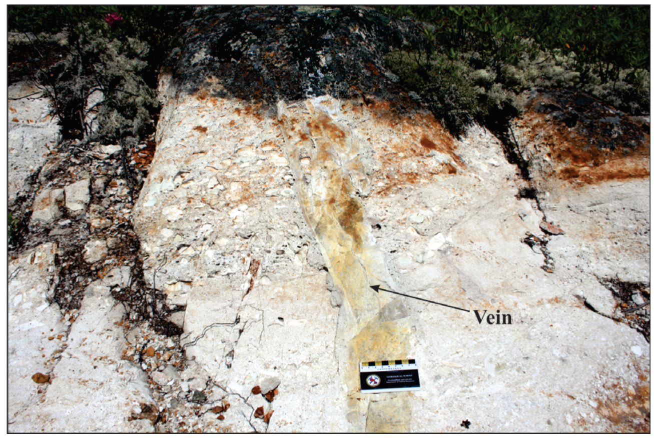

Plate 8. *Pale-weathering, silica-altered host rocks within the Big Easy prospect; note the relict rounded clasts and the local development of an approximately 10-cm-wide colloform–crustiform-banded chalcedonic silica vein crosscutting bedding at a relatively high angle.*

Plate 9. *Interlayered, pale-grey chalcedonic silica and thin-bedded coarse-grained volcaniclastic sandstone interpreted to be correlative with Musgravetown Group.*

(Plate 11) containing up to 4.4 g/t Au (Silver Spruce Resources, Press Release, June 16, 2009) along a newly constructed woods road located near the southwestern side of Bonavista Bay (Figure 1). Spectral analysis of mineralized samples from the Calvin's Landing prospect reveal the presence of alunite and pyrophyllite alteration in association with abundant specularite; characteristics that are typical of high-sulphidation-style mineralization in the Burin Peninsula region (*e.g.,* O'Brien *et al*., 1999).

Limited trenching in the area failed to uncover the source of the mineralized float, but did identify strongly foliated muscovite–pyrite alteration containing weakly anomalous gold values (up to 94 ppb Au over 2.2 m; Silver Spruce Resources, Press Release, September 15, 2009). Regional geology maps of the area indicate that the alter-

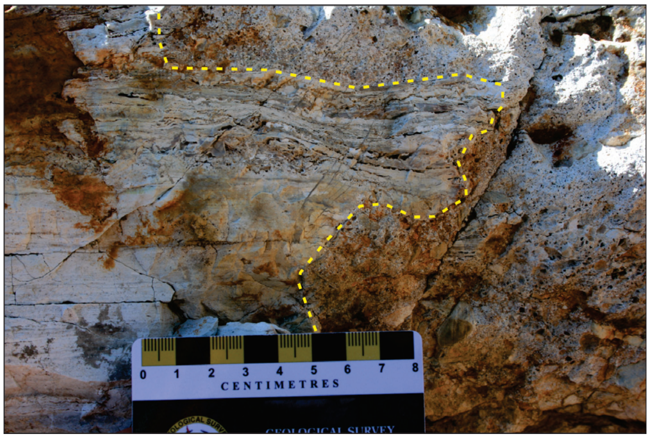

Plate 10. *Large fragment of layered chalcedonic silica (outlined in yellow), displaying sharp angular margins, occurring as a clast within coarse-grained volcaniclastic sandstone and lesser interbedded pebble conglomerate.*

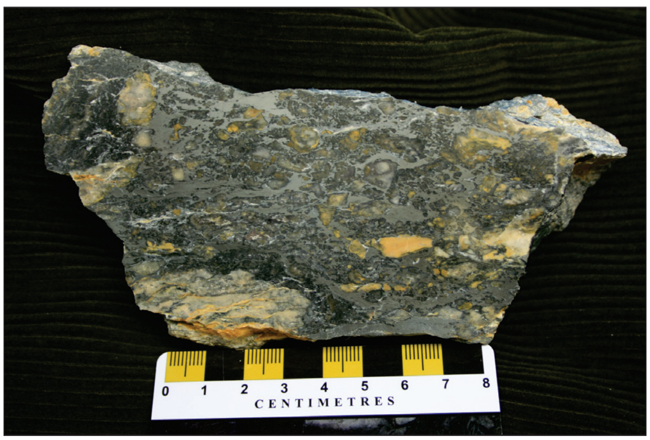

Plate 11. *Photograph of mineralized specularite–quartz–alunite float from the Calvin's Landing prospect. Photo courtesy of the Matty Mitchell Prospectors Resource Room.*

ation is situated within sedimentary rocks of the Musgravetown Group, marginal to a belt of moderately to highly strained felsic volcanic rocks located immediately to the west, where they are structurally juxtaposed with gneissic rocks of the Gander Zone (O'Brien *et al*., 1991a). The strong alteration masks the identity of the protolith for the auriferous float; however the muscovite–pyrite alteration discovered in outcrop is reported to locally grade outward into unaltered sedimentary rocks of the Musgravetown Group (Silver Spruce Resources, Press Release, September 15, 2009).

In the vicinity of Magic Arm (Figure 1), extensive zones of pyritic alteration and silicification are reported to be developed within a northeast-trending belt of volcanic rock assigned to the Love Cove Group (O'Brien, 1987). This belt of alteration is locally up to 600 m wide, and contains zones of silicification measuring up to 200 m in width; these localized zones of silicification are consistently anomalous with respect to gold and return assays of up to 110 ppb Au (O'Brien *op. cit.*). A recent discovery by a local prospector, immediately to the south of the Magic Arm–Hail Island alteration zone consists of copper–antimony–zinc–silver mineralization in association with anomalous gold, mercury, selenium and tellurium (Cull's Harbour prospect; Figure 1). Assays from the area have returned values of up to 3.7% Cu, 2.1% Sb, 0.46% Zn, 1101 g/t Ag, 449 ppb Au, 130 ppm Hg, 4.5 ppm Se and 0.04 ppm Te (Culls Harbour, 2011). This mineralization is situated proximal to the Louil Hills Intrusive Suite (Figure 1), which has previously been recognized as having potential to host porphyry-style mineralization (*e.g.,* Magic River prospect; Sparkes, 2000). Preliminary investigations by the author in the area of the Cull's Harbour prospect indicate that mineralization is associated with iron-carbonate alteration and associated brecciation hosted within fine- to medium-grained plutonic rocks, inferred to be correlative with the adjacent Louil Hills Intrusive Suite (Plate 12). The exact nature of this mineralization and its potential link with the nearby alteration remain unknown.

Plate 12. *Mineralized grab samples from the Cull's Harbour prospect displaying brecciation and associated iron-carbonate alteration. Photo courtesy of the Matty Mitchell Prospectors Resource Room.*

DISCUSSION AND CONCLUSION

The presence of both high- and low-sulphidation styles of epithermal mineralization within the volcano-sedimentary rocks of the western Avalon Zone indicates that this area is prospective with regards to hosting potentially economic gold mineralization. Ongoing exploration continues to identify new occurrences and mineralizing environments. The recent recognition of high-sulphidation-style mineralization, combined with other occurrences within the area of Bonavista Bay, demonstrates the considerable strike length of this mineralized terrain. These epithermal systems are hosted within the *ca.* 595–565 Ma Marystown Group, the *ca.* 570–550 Ma Long Harbour Group, as well as the *ca.* 570 Ma and younger Musgravetown Group. It remains to be determined whether these epithermal systems are linked with a single mineralizing event, or represent the development of multiple hydrothermal systems over a long and protracted period of time throughout the western Avalon Zone. The existing geochronological constraints on hydrothermal systems elsewhere within the Avalon Zone (*e.g.,* the *ca.* 620 Ma Butlers Pond prospect; Sparkes *et al.*, 2002; the *ca.* 605–600 Ma Lodestar prospect; Hinchey, 2001; the *ca.* 585–580.5 Ma Oval Pit deposit; Sparkes *et al*., 2005; the *ca.* 578–574 Ma Hope Brook deposit; Dubé *et al*., 1995) and the presence of multiple intrusive events within the region provide supporting evidence for the generation of multiple hydrothermal systems over a protracted period of time.

Recent recognition of potential porphyry-related mineralization provides additional target environments for ongoing and future exploration. Broad areas of low-grade Cu–Au mineralization, such as that developed within the Stewart prospect, demonstrate such a target. The development of both pyrophyllite and illite alteration in association with a quartz-diorite intrusion suggests the presence of a telescoped epithermal-porphyry system (Dyke and Pratt, 2007). Further work is required to unravel the complex relationships between the illite and pyrophyllite alteration, which is locally superimposed upon chloritic alteration within the central core of the hydrothermal system. The discovery of bonanza-grade mineralization displaying low-sulphidation characteristics along strike from Stewart at the Forty Creek prospect further emphasizes the diversity of mineralization within these epithermal systems.

High- and low-sulphidation styles of epithermal mineralization within volcanic rocks of the Long Harbour Group represent some of the youngest examples of such within the Avalon Zone. The local preservation of high-level textural features within low-sulphidation-style chalcedonic silica veins demonstrates the well-preserved nature of these epithermal systems.

Ongoing mineralogical work coupled with geochronological studies under this project are aimed at better understanding the nature and timing of these late Neoproterozoic epithermal systems in the western part of the Avalon Zone. This insight will hopefully provide information that can be applied throughout the region to aid in the recognition of epithermal-style mineralization and identify potential host sequences that have yet to be explored in detail.

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REFERENCES

Anderson, M.M., Bruckner, W.D., King, A.F. and Maher, J.B.
1975: The Late Proterozoic 'H.D. Lilly Unconformity' at Red Head, northeastern Avalon Peninsula, Newfoundland. American Journal of Science, Volume 275, pages 1012-1027.

Arribas, A. Jr., Cunningham, C.G., Rytuba, J.J., Rye, R.O., Kelly, W.C., Podwysocki, M.H., McKee, E.H. and Tosdal, R.M.
1995: Geology, geochronology, fluid inclusions, and isotope geochemistry of the Rodalquilar gold alunite deposit, Spain. Economic Geology, Volume 90, pages 795-822.

Ayuso, R.A., Wooden, J.L., Foley, N.K., Seal, R.R. II and Sinha, A.K.
2005: U-Pb zircon ages and Pb isotope geochemistry of gold deposits in the Carolina Slate Belt of South Carolina. Economic Geology, Volume 100, pages. 225-252.

Bell, R.
1989: First year assessment report on prospecting and geochemical exploration for the Fortune project for licence 3387 on claim block 5067 and licence 3388 on claim blocks 5064-5066 in the Bart Pond, Deer Park Pond, Taylors Mountain Pond and Blind Pond areas, southeastern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/10/0295, 48 pages.

Blackwood, R.F. and Kennedy, M.J.
1975: The Dover Fault: Western boundary of the Avalon Zone in northeastern Newfoundland. Canadian Journal of Earth Sciences, Volume 12, pages 320-325.

Churchill, R.
2001: First year assessment report on prospecting for licences 7374M-7375M on claims in the Cross Hills area, Fortune Bay, southern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/10/0455, 18 pages.

Crewe, T. M. and Seymour, C. R.
2007: Fifth year assessment report on geological, geochemical and trenching exploration for licence 10928M

on claims in the Long Harbour area, Fortune Bay, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/11/0627, 53 pages.

"Culls Harbour – Copper-Antimony-Zinc-Silver" Online
2011: The Matty Michel Prospectors Resource Room. <http://www.nr.gov.nl.ca/nr/mines/prospector/matty_mitchell/pdf/Gold/Cull's%20Harbour%20Cu-Zn-Sb-Au.pdf>.

Dallmeyer, R.D., Hussey, E.M., O'Brien, S.J. and O'Driscoll, C.F
1983: Chronology of tectonothermal activity in the western Avalon Zone of the Newfoundland Appalachians. Canadian Journal of Earth Sciences, Volume 20, pages 355-363.

Degagne, P. and Robertson, D. J.
1985: Second year assessment report on geological and geochemical exploration for licence 2372 on claim block 1610 in the Monkstown Road area on the Burin Peninsula, southern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/09/0233, 39 pages.

Dimmell, P. and MacGillivray, G.
1993: The Stewart gold zone, Burin Peninsula, eastern Newfoundland. *In* Ore Horizons. *Compiled by* A. Hogan and H.S. Swinden, Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Ore Horizons, Volume 2, pages 19-36.

Dimmell, P.M., MacGillivray, G. and Hoffman, S. J.
1992: Second year assessment report on geochemical and diamond drilling exploration for licence 3497 on claim block 6284 in the Hickey's Pond area on the Burin Peninsula, eastern Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File 1M/16/0326, 139 pages.

1991: First year assessment report on geological and geochemical exploration for licence 3961 on claim blocks 5297-5301 in the Heffern Pond, Paradise River and Monkstown Road areas on the Burin Peninsula, eastern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/0324, 158 pages.

Dimmell, P., MacGillivray, G. and Pickett, J.W.
1990: Fifth year assessment report on geological and geochemical exploration for licence 2941 on claim blocks 4132-4134 in the Camp Pond and Powderhorn Pond areas on the Burin Peninsula, eastern Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File 1M/0317, 142 pages.

Dong, G., Morrison, G. and Jaireth, S.
1995: Quartz textures in epithermal veins, Queensland–classification, origin, and implication. Economic Geology, Volume 90, pages 1841-1856.

Dubé, B., Dunning, G. and Lauziere, K.
1995: Geology of the Hope Brook Mine, Newfoundland, Canada: A preserved Late Proterozoic high-sulphidation epithermal gold deposit and its implications for exploration. Economic Geology, Volume 93, pages 405-436.

Dunning, G.R., O'Brien, S.J., Colman-Sadd, S.P., Blackwood, R.F., Dickson, W.L., O'Neill, P.P. and Krogh, T.E.
1990: Silurian orogeny in the Newfoundland Appalachians. Journal of Geology, Volume 98, No. 6, pages 895-913.

Dyke, B. and Pratt, W.
2007: First, second, third, fifth and sixth year assessment report on geological, geochemical and trenching exploration for licences 8405M-8406M, 8509M, 9038M, 10975M, 11092M, 12650M, 13189M, 13633M, 13637M-13640M, 14825M, 14827M and 14833M on claims in the Hickeys Pond and Powderhorn Hill areas, on the Burin Peninsula, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/0698, 317 pages.

Harris, J.
1996: First and second year assessment report on geological and geochemical exploration for licence 4554 on claim 17112 and licence 4679 on claim block 8474 in the Henrys Pond area, eastern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2D/0312, 29 pages.

Hayes, A.O.
1948: Geology of the area between Bonavista and Trinity Bays, eastern Newfoundland. Newfoundland Geological Survey, Bulletin 32, pages 1-37.

Hinchey, J.G.
2001: An integrated geochemical, petrologic, geochronological, and metallogenic study of the Powder Horn Intrusive Suite and the associated Lodestar Prospect - a magmatic-hydrothermal auriferous breccia zone that links epithermal and porphyry systems, northern Burin Peninsula, Newfoundland. M.Sc. thesis, Memorial University of Newfoundland, St. John's, Canada, 327 pages.

Hopfengaertner, F.
1982: First year assessment report on geological, geo-

chemical and geophysical exploration for licence 1989 on claim block 2455 in the Grand Le Pierre area, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/10/0205, 19 pages.

Huard, A. and O'Driscoll, C.F.
1985: Auriferous specularite-alunite-pyrophyllite deposits of the Hickey's Pond area, northern Burin Peninsula, Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 85-1, pages 182-189.

1986: Epithermal gold mineralization in the late Precambrian rocks on the Burin Peninsula. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, pages 65-78.

Hussey, E.M.
2006: First year assessment report on compilation and geological and geochemical exploration for licence 10503M on claims in the Rocky Hills area, near English Harbour East, Fortune Bay, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/10/0574, 273 pages.

1978: Sound Island map-area [west half]. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Open File 1M/16/0212, 40 pages.

1979: The stratigraphy, structure and petrochemistry of the Clode Sound map area, northwestern Avalon Zone, Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland, St John's, Newfoundland, 335 pages.

Kennedy, M.J., Blackwood, R.F., Colman-Sadd, S.P., O'Driscoll, C.F. and Dickson, W.L.
1982: The Dover-Hermitage Bay Fault: boundary between the Gander and Avalon Zones, eastern Newfoundland. *In* Major Structural Zones and Faults of the Northern Appalachians. *Edited by* P. St-Julyien and J. Beland. Geological Association of Canada, Special Paper, Number 24, pages 231-247.

Kerr, A., Rafuse, H., Sparkes, G., Hinchey, J. and Sandeman, H.A.
2011: Visible/infrared spectroscopy [VIRS] as a research tool in economic geology: background and pilot studies from Newfoundland and Labrador. *In* Current Research. Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 11-1, pages 145-166.

MacGillivray, G.C. and Lechow, W.R.
1985: First, second and fourth year assessment report for the Ackley and Sage Pond projects on geological, geochemical and geophysical exploration for licence 2281 on claim block 2495, licence 2331 on claim block 2759, licence 2465 on claim block 3847, licence 2466 on claim block 3849, licence 2475 on claim block 3850, licence 2476 on claim blocks 3851 and 3853 and licence 2477 on claim block 3854 in the Long Harbour area, Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File 1M/10/0226, 183 pages.

Mills, J., O'Brien, S.J., Dubé, B., Mason, R. and O'Driscoll, C.F.
1999: The Steep Nap Prospect: a low-sulphidation, gold-bearing epithermal vein system of late Neoproterozoic age, Avalon Zone, Newfoundland Appalachians. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Geological Survey, Report 99-1, pages 255-274.

Meyer, J., Tomlin, S. and Green, R.
1984: Mineral occurrence map, Gander Lake, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Map 84-045.

O'Brien, S.J.
2002: A note on Neoproterozoic gold, early Paleozoic copper and basement-cover relationships on the margins of the Holyrood Horst, southeastern Newfoundland. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Geological Survey, Report 02-1, pages 219-227.

1993: A preliminary account of geological investigations in the Clode Sound-Goose Bay region, Bonavista Bay, Newfoundland [NTS 2C5/NW and 2D8/NE]. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Geological Survey Branch, Report 93-1, pages 293-309.

1987: Geology of the Eastport (west half) map area, Bonavista Bay, Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 87-1, pages 257-270.

O'Brien, S.J. and Holdsworth, R.E.
1992: Geological development of the Avalon Zone, the easternmost Gander Zone, and the ductile Dover Fault in the Glovertown [NTS 2D/9, east half] map area, eastern Newfoundland. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy,

Geological Survey Branch, Report 92-1, pages 171-184.

O'Brien, S.J. and Knight, I.
1988: The Avalonian geology of southwest Bonavista Bay: portions of the St Brendans [2C/13] and Eastport [2C/12] map areas. *In* Current Research. Newfoundland and Labrador Department of Mines, Mineral Development Division, Report 88-1, pages 193-205.

O'Brien, S.J. and Taylor, S.W.
1983: Geology of the Baine Harbour (1M/7) and point Enragee (1M/6) map areas, southeastern Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-5, 70 pages.

O'Brien, S. J., Dubé, B. and O'Driscoll, C. F.
1999: High-sulphidation, epithermal-style hydrothermal systems in late Neoproterozoic Avalonian rocks on the Burin Peninsula, Newfoundland: implications for gold exploration. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Geological Survey, Report 99-1, pages 275-296.

O'Brien, S.J., Dubé, B., O'Driscoll, C.F. and Mills, J.
1998: Geological setting of gold mineralization and related hydrothermal alteration in late Neoproterozoic [post-640 Ma] Avalonian rocks of Newfoundland, with a review of coeval gold deposits elsewhere in the Appalachian Avalonian belt. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Geological Survey, Report 98-1, pages 93-124.

O'Brien, S.J., O'Brien, B.H., Dunning, G.R. and Tucker, R.D.
1996: Late Neoproterozoic evolution of Avalonian and associated peri-Gondwanan rocks of the Newfoundland Appalachians. *In* Avalonian and Related Terranes of the Circum-North Atlantic. *Edited by* M.D. Thompson and R.D. Nance. Geological Society of America, Special Paper 304, pages 9-28.

O'Brien, S.J., O'Driscoll, C.F., Greene, B.A. and Tucker, R.D.
1995: Pre-carboniferous geology of the Connaigre Peninsula and the adjacent coast of Fortune Bay, southern Newfoundland. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Geological Survey, Report 95-1, pages 267-297.

O'Brien, S.J., O'Driscoll, C.F., Tucker, R.D. and Dunning, G.R.
1994: Late Precambrian geology and volcanogenic massive sulphide occurrences of the southwestern Avalon Zone, Newfoundland. *In* Report of Activities. Newfoundland and Labrador Department of Natural Resources, Geological Survey Branch, pages 77-81.

O'Brien, S.J., Tucker, R.D., Dunning, G.R. and O'Driscoll, C.F.
1992: Four-fold subdivision of the Late Precambrian magmatic record of the Avalon Zone type area (East Newfoundland): Nature and significance. Geological Association of Canada, Abstracts with Program, Annual Meeting, Volume 17, page A85.

O'Brien, S.J., O'Neil, P.P. and Holdsworth, R.E.
1991a: Preliminary geological map of part of the Glovertown [2D/9] map area, Newfoundland. Newfoundland and Labrador Department of Mines and Energy, Geological Survey Branch, Open File 2D/09/0260, Map 91-169.

O'Brien, S. J., O'Brien, B. H., O'Driscoll, C.F., Dunning, G.R., Holdsworth, R.E. and Tucker, R.
1991b: Silurian orogenesis and the northwestern limit of Avalonian rocks in the Hermitage Flexure, Newfoundland Appalachians. Geological Society of America, Abstracts with Programs, Volume 23, No. 1, page 109.

O'Brien, S.J., Strong, D.F. and King, A.F.
1990: The Avalon Zone type area: southeastern Newfoundland Appalachians. *In* Avalonian and Cadomian Geology of the North Atlantic. *Edited by* R.A. Strachan and G.K. Taylor. Blackies and Son Ltd., Glasgow, pages 166-194.

O'Brien, S.J., Dunning, G.R., Knight, I. and Dec, T.
1989: Late Precambrian geology of the north shore of Bonavista Bay [Clode Sound to Lockers Bay]. *In* Report of Activities. Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, pages 49-50.

O'Brien, S.J., Nunn, G.A.G., Dickson, W.L. and Tuach, J.
1984: Geology of the Terrenceville (1M/10) and Gisborne Lake (1M/15) map areas, southeast Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 84-4, 54 pages.

O'Driscoll, C.F.
1984: The Hickey's Pond Belt: auriferous specularite-alunite-pyrophyllite-sericite mineralization near Placentia Bay, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Open File Report 1M/16(221), 12 pages.

Reusch, D.N. and O'Driscoll, C.F.
1987: Geological and metallogenic investigations in the western belt of the Love Cove Group [NTS 2D/1, 2, 8], Avalon Zone, Newfoundland. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Mineral Development Division, Report 87-1, pages 93-101.

Scheetz, J.W.
1991: The geology and alteration of the Brewer gold mine, Jefferson, South Carolina. Unpublished M.Sc. thesis, University of North Carolina, Chapel Hill, North Carolina, 180 pages.

Seymour, C.R.
2006: Second and third year assessment report on prospecting and geochemical exploration for licences 10148M and 10928M on claims in the Long Harbour area, southern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/11/0585, 41 pages.

2004: First year assessment report on prospecting and geochemical exploration for licences 9636M-9640M and 10148M on claims in the Long Harbour area, Fortune Bay, Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 1M/11/0515, 53 pages.

Sexton, A., Heberlein, K. and Thompson, A. J. B.
2003: First and second year assessment report on geological and geochemical exploration for licences 8102M, 8405M, 8509M, 8976M-8977M and 9039M on claims in the Paradise River area, on the Burin Peninsula, Newfoundland, 2 reports. Newfoundland and Labrador Geological Survey, Assessment File 1M/0468, 73 pages.

Sparkes, B.A.
2000: First year assessment report on prospecting and geochemical exploration for licences 6377m-6378m on claims in the Northeast Arm area, near Glovertown, eastern Newfoundland. Newfoundland and Labrador Geological Survey, Assessment File 2C/12/0093, 37 pages.

Sparkes, G.W., O'Brien, S.J., Dunning, G.R. and Dubé, B.
2005: U–Pb geochronological constraints on the timing of magmatism, epithermal alteration and low-sulphidation gold mineralization, eastern Avalon Zone, Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey, Report 05-1, pages 115-130.

Sparkes, B.A., O'Brien, S.J., Wilson, M.R. and Dunning, G.R.
2002: The geological setting, geochemistry and age of late Proterozoic intrusive rocks at the Butlers Pond Cu–Au prospect (NTS 1N/3) Avalon Peninsula, Newfoundland. *In* Current Research. Newfoundland and Labrador Department of Mines and Energy, Geological Survey, Report 02-1, pages 245-264.

Strong, D.F. O'Brien, S.J., Taylor, S.W., Strong, P.G. and Wilton, D.H.
1978a: Geology of Marystown (1M/3 and St. Lawrence 1L/14) map areas, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 77-8, 81 pages.

Strong, D.F. O'Brien, S.J., Taylor, S.W., Strong, P.G. and Wilton, D.H.
1978b: Aborted Proterozoic rifting in eastern Newfoundland. Canadian Journal of Earth Sciences, Volume 15, pages 117-131.

Taylor, S.W., O'Brien, S.J. and Swinden, H.S.
1979: Geology and mineral potential of the Avalon Zone and granitoid rocks of eastern Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 79-3, 50 pages.

Tuach, J.
1991: The geology and geochemistry of the Cross Hills Plutonic Suite, Fortune Bay, Newfoundland [NTS 1M/10], an Eocambrian to Cambrian alkaline gabbro-granodiorite-granite-peralkaline granite-syenite suite containing minor Zr-Y-Nb-REE mineralization. Newfoundland and Labrador Department of Mines and Energy, Geological Survey Branch, Report 91-02, 86 pages.

Younce, G.B.
1970: Structural geology and stratigraphy of the Bonavista Bay region, Newfoundland. Ph.D. thesis, Ithaca, New York, Cornell University, 188 pages.

White, N.C. and Hedenquist, J.W.
1995: Epithermal gold deposits: styles, characteristics and exploration. Society of Economic Geologists Newsletter, Number 23, pages 9-13.

Williams, H.
1979: Appalachian Orogen in Canada. Canadian Journal of Earth Sciences, Volume 16, pages 792-807.

1971: Geology of Belleoram map-area, Newfoundland. Geological Survey of Canada, Paper 70-65, 39 pages.

Widmer, K.
1950: The geology of the Hermitage Bay area, Newfoundland. Ph.D. thesis, Princeton, New Jersey, Princeton University, 439 pages.

van Staal, C.R.
2007: Pre-Carboniferous tectonic evolution and metallogeny of the Canadian Appalachians. *In* Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods. *Edited by* W.D. Goodfellow. Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, pages 793-818.