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GOLD AND ANTIMONY OCCURRENCES OF THE EXPLOITS SUBZONE AND GANDER ZONE: A REVIEW OF RECENT DISCOVERIES AND THEIR INTERPRETATION

G.C. Squires[1]
Mineral Deposits Section

ABSTRACT

Recent exploration work in the northeastern Dunnage Zone indicates that gold and antimony mineralization is structurally controlled and mostly of Silurian or younger age. Most of the occurrences investigated are associated with relatively deeply formed (ca. 5 km), late-orogenic quartz veins, e.g., Golden Promise (Jaclyn), Knob, Dome and Titan. Other gold occurrences exhibit textures indicative of emplacement at a shallow depth (ca. <1 km), in a low-sulphidation epithermal environment. Textures such as silicification, multiple chalcedonic veining, bladed quartz (after calcite or barite) and cockade-textured breccias are all indicative of cooler, near surface precipitation, e.g., the Mustang, Horwood and Stallion occurrences. Antimony mineralization at the Beaver Brook mine occurs in monomineralic veins and carbonate- or quartz–carbonate-bearing vugs, and also exhibit textures indicative of a low-sulphidation epithermal environment. A number of occurrences in the Indian Islands Group, e.g., Jasperoid, Barite, Road Breccia, Clarks Brook East and O'Reilly, display features suggested by previous work to be indicative of a Carlin-style environment, e.g., the association with silicified carbonate rocks ('jasperoid') and the "toxic-element suite", including Au, As, Sb, Pb and Ba. However, on the basis of texture, it is difficult to clearly distinguish Carlin-style alteration from that which may have been produced by epithermal systems.

The Mount Peyton Intrusive Suite has been proposed as a possible thermal source for the surrounding epithermal occurrences. However, some of this mineralization is clearly later than the intrusive suite, suggesting that either a different heat source must be sought or that there is more than one age of epithermal mineralization.

The plethora of very recent high-grade gold discoveries in the area, often found by simple prospecting, highlights the potential of the area to generate quality gold and antimony prospects.

INTRODUCTION

The principal aim of the current project is to provide a preliminary description of some of the recently discovered epigenetic gold occurrences in the Ordovician to Silurian sequences of the eastern Dunnage and western Gander zones (Figure 1). A related goal is to categorize the mineralization in the context of modern metallogenic models. Recent field work has also highlighted the similarities between the settings of both epigenetic gold mineralization and local antimony mineralization around the dormant Beaver Brook antimony mine. The relationship between antimony and gold mineralization was, therefore, made an additional component of this study.

REGIONAL GEOLOGY

The study area is located at the northern end of the Paleozoic Appalachian Orogen, which has been subdivided into the Humber, Dunnage, Gander and Avalon tectonostratigraphic zones (Williams, 1979; Figure 1). The Humber Zone in the west comprises Paleozoic sedimentary rocks that were deposited on Grenvillian basement of the eastern margin of the Laurentian (North American) continent. The Gander Zone in the east encompasses sedimentary rocks that were formed in proximity to the Gondwanan (African) continental margin (Colman-Sadd, 1980; Blackwood, 1982). Between these two continental margin terranes, the Dunnage Zone comprises a structurally telescoped assem-

[1] Present address: Messina Minerals Inc., Vancouver, BC.

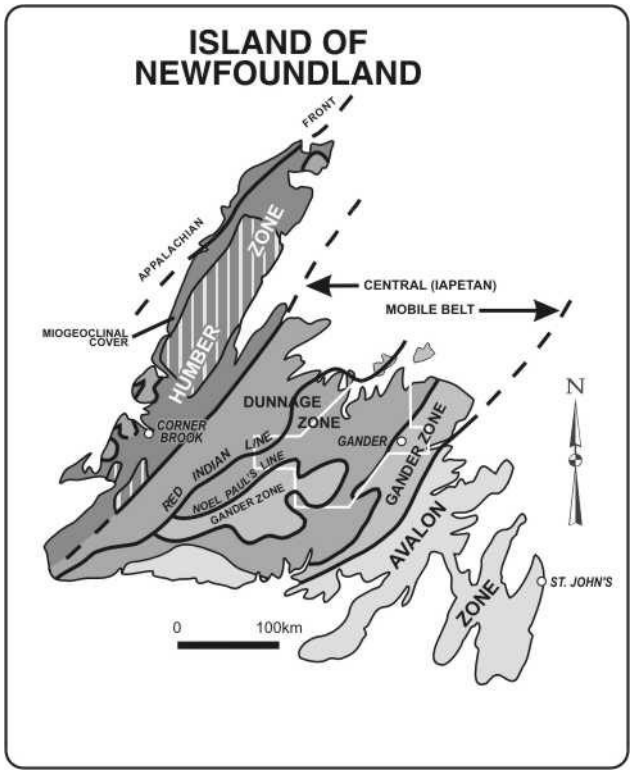

Figure 1. *Tectonic zones of Newfoundland. Location of the study area is outlined by the heavy white outline and shown in more detail in Figure 2.*

blage of ophiolitic and arc- to back-arc-volcanic rocks, plus volcaniclastic to epiclastic sedimentary rocks that collectively represent remnants of early to middle Paleozoic oceanic terranes.

The Dunnage Zone is divided by a series of faults termed the Red Indian Line, that are considered to mark the main suture zone in this part of the Appalachian Orogen. The part of the Dunnage Zone north of the Red Indian Line is known as the Notre Dame Subzone, and the part south of the line is known as the Exploits Subzone (Williams *et al*., 1988). These are inferred to have formed on opposite sides of the Iapetus Ocean (Neuman, 1984; Colman-Sadd *et al*., 1992).

Exploits Subzone

The northeastern Exploits Subzone is divided into two dominant sedimentary successions that are separated by the Silurian (or younger) Dog Bay Line, a series of faults thought by Williams *et al.* (1993) to mark a major Silurian tectonic boundary – possibly a suture zone (Figure 2).

Exploits Subzone, East of Dog Bay Line

The Exploits Subzone, east of the Dog Bay Line consists mainly of the Davidsville Group, a sequence of Cambro-Ordovician silicilastic rocks that youngs to the west into rocks of deeper water setting (Blackwood, 1982), and which is, in part, volcanogenically derived. In the east, this group lies unconformably upon the structurally complex volcanic, plutonic and ophiolitic rocks of the Gander River Complex (O'Neill and Blackwood, 1989). The Gander River Complex, and where it is absent, the Davidsville Group, are in tectonic contact with the structurally underlying Gander Group to the east (Williams, 2001, p. 82).

The upper part of Davidsville Group consists of graphitic–sulphidic shale and chert of Caradocian age, which are succeeded by limestone, siltstone, shale and redbeds of the Silurian Indian Islands Group (Williams *et al*., 1993). The Indian Islands Group is relatively well defined in the coastal area around Gander Bay, and has also been recognized by Dickson (1996) to extend for some distance along the southeastern side of the Mount Peyton Intrusive Suite (Figure 2). There is a gap between the two areas that is occupied by thinly bedded red shale and siltstone of the Ten Mile Lake Formation (Currie, 1997), which in Figure 2 has been included as part of the Botwood Group. The basal contact of the Indian Islands Group with the Davidsville Group is not observed, but has been interpreted to be conformable, where not structurally modified (Williams *et al.*, 1993). The most easterly exposed outcrops of the Indian Islands Group, immediately east of the Northwest Gander River, are fault brecciated and calcite veined, having a flat to gently dipping structural fabric that is probably related to overthrusting by the adjacent Davidsville Group. The western contact of the group with the Mount Peyton Intrusive Suite also appears to be faulted. The actual contact is not seen but in stream sections, e.g., Clarkes' Brook, the granite adjacent to the contact is heavily brecciated and locally sheared, suggesting a brittle fault. Just east of the contact with the Mount Peyton Intrusive Suite, in Careless Brook, as well as along strike to the southwest near the Beaver Brook mine, the Indian Islands Group includes lenticular fault-bounded zones of sheared Caradocian sulphidic–graphitic shale, indicating considerable structural complexity in this area.

Exploits Subzone, West of Dog Bay Line

The Exploits Subzone, west of the Dog Bay Line consists of the Cambrian to Silurian rocks of the Victoria Lake Supergroup and the Badger and Botwood groups. The Victoria Lake Supergroup is Cambro-Ordovician in age, and consists of a lower series of calc-alkalic volcanic rocks, intercalated with, and overlain by, deep-water volcanogenic sandstone and shale, and capped by Caradocian black graphitic–sulphidic shale. The supergroup is conformably overlain by the Badger Group, which ranges from Late Ordovician to Early Silurian and consists of a shallowing-

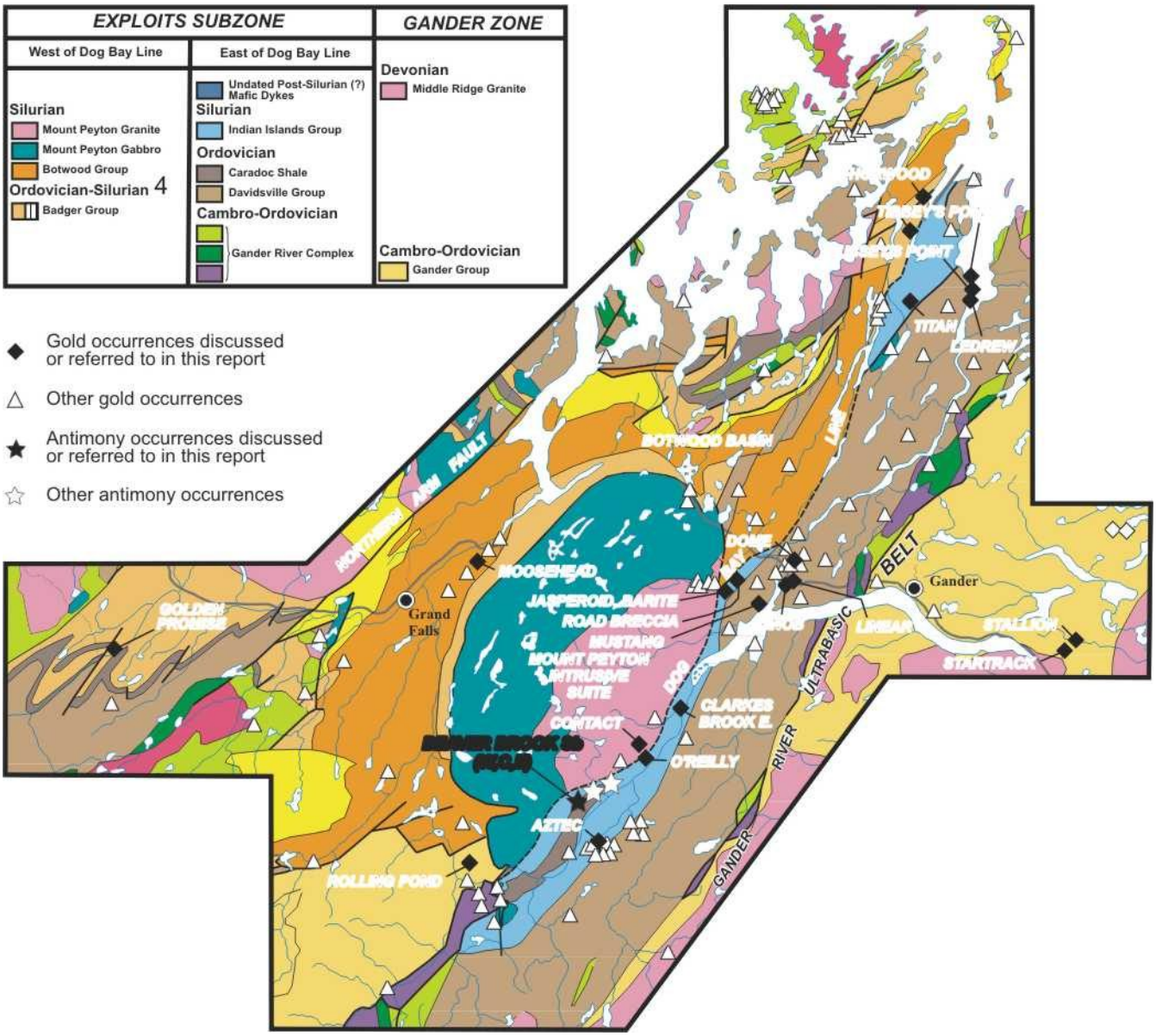

Figure 2. *Generalized geology of the northeastern Dunnage and western Gander zones, showing mineral occurrences mentioned in the text.*

upward sequence of deep- to shallow-water marine conglomerates and sandstones. These pass gradationally upward into the continentally derived red arkoses of the Silurian Botwood Group (Williams *et al.*,1993). The Badger Group is intruded by the eliptical Mount Peyton Intrusive Suite, which consists of an older gabbroic phase dated at 424 Ma (Dunning, 1994) and a younger granitic phase, the age of which is not well established. Contacts of the Mount Peyton Intrusive Suite with the Botwood Group have not been observed and the age of the intrusive suite with respect to that unit remains unknown.

The Dog Bay Line was likely a long-lived Silurian feature that separated the shallow-marine to terrestrial depositional setting of the Botwood Group from the deep- to shallow-marine setting of the Indian Islands Group. The age of latest movement along the Dog Bay Line is unknown but if the fault that separates the Indian Islands Group from the Mount Peyton Intrusive Suite is a continuation of the Dog Bay Line, then the latest movement must be post-plutonic.

A term that has featured prominently in exploration reports and press releases in recent years, but that has not

been clearly defined, is "Botwood basin". In most cases this has been used to refer to the geographic extent of the Silurian rocks of the Botwood and Indian Islands groups; however, in some exploration company press releases it has been used (inappropriately) to include large areas of adjacent Badger Group and other units. The term "basin" is somewhat misleading because a) the Botwood and Indian Islands groups are structurally preserved remnants of originally more extensive sequences, rather than depositional centres, and b) the "basin" likely comprises radically different, and possibly geographically separated, depositional environments on either side of the Dog Bay Line. The term has, however, attained common usage, hence the need to clarify its meaning.

Gander Zone

This is formed predominantly by the Cambro-Ordovician metasedimentary rocks of the Gander Group and consists (Blackwood, 1982; O'Neill and Colman-Sadd, 1993) of a lower unit, the Jonathan's Pond Formation (psammite, quartzite and pelite) and an upper unit, the Indian Bay Big Pond Formation (conglomerate, sandstone and siltstone). In the west, the Gander Group is structurally overlain by the Gander River Complex and Davidsville Group. Deformation and metamorphism in the Gander Group has produced polyphase folding and greenschist- to amphibolite-facies assemblages.

DESCRIPTIONS OF SELECTED GOLD OCURRENCES

GOLDEN PROMISE PROSPECT (JACLYN ZONE) (UTM 562400mE, 5417200mN)

The description of this prospect is adapted entirely from Copeland (2004). In spring, 2002a, local prospector, Mr. William Mercer, collected samples from quartz float that was exposed following a major forest fire in 1999. A composite sample, collected from about 10 boulders, gave an assay of about 30 g/t gold. Rubicon Minerals Corporation then optioned what became known as the Golden Promise property from Mr. Mercer in May 2002. Subsequent drilling resulted in discovery of the source of the boulders in the underlying Jaclyn zone veins. These are located 500 m northwest of the Buchans Highway, about 11.5 km from its intersection with Trans-Canada Highway at Badger.

The central vein system of the Golden Promise prospect (Figure 2), containing the Jaclyn zone veins, is hosted within Lower to Middle Ordovician metasedimentary rocks of the Victoria Lake Supergroup and the overlying (recently redefined as early Lower Ordovician) Caradocian shale. The vein system strikes 070 to 090° and dips subvertically (80 to 85°) to the southeast, although in the east it dips steeply to the northwest, and attains an estimated true thickness of close to 4 m, with individual veins up to 2.7 m thick. Drilling to date indicates that the area of known gold mineralization extends to a maximum vertical depth of 192 m along a strike length of 375 m. No resource estimate has been released for the zone, but some of the better reported true-width intersections are 16.57 g/t gold over 1.64 m and 23.14 g/t gold over 0.67 m (Rubicon Minerals Corporation, press release, September 19, 2002). About 92 percent of 26 completed holes have intersected the vein and 77 percent of holes contain visible gold. Drillholes GP03-31, -32 and -33 have shown that the adjacent Jaclyn North zone (200 m to the northwest) and Jaclyn South zone (300 m to the southeast) boulder trains are underlain by highly altered sedimentary rocks that also host quartz veins containing visible gold.

The gold-bearing quartz veins of the Jaclyn zone are milky white to grey, comb-textured to locally vuggy, often stylolitic to banded, and inclusion rich (Plates 1 and 2). Overall, these indicate open-space filling in an extensional tectonic setting. Visible-gold distribution within a vein is generally restricted to 10 to 20 cm thick zones, often close to vein margins. Gold occurs as: i) specks and flakes (0.1 mm to 3 mm across) along short fractures oriented perpendicular to the vein margin and along the boundaries of comb-quartz crystals; ii) along stylolitic seams in association with fine-grained arsenopyrite; iii) as scattered specks along rusty fractures parallel to the vein boundary; and iv) less commonly as isolated grains in massive quartz. Accessory minerals include calcite, chlorite, sericite, iron carbonate, arsenopyrite, pyrite, galena, sphalerite, and chalcopyrite. Wallrock inclusions locally contain abundant arsenopyrite and lesser pyrite. The veins are hosted predominantly by bedded mudstone/greywacke intercalated with arkosic greywacke and massive arkose that locally contain mudstone clasts up to 2 cm long. The stratigraphy is right-way-up and dips shallowly to the north-northeast.

Alteration associated with the veining extends up to 15 m into the wallrock, but varies according to rock type. The most pronounced alteration is developed in fine-grained mudstone, where light-green silica–sericite–carbonate alteration is developed as 1 to 10 mm spots and along fractures (Plate 3). These types locally coalesce into massive alteration. A 0.5- to 1.2-m-thick mafic dyke cuts all rock types including the mineralized quartz vein.

The nature of the veining, mineralization, alteration, host rock and tectonism at the Jaclyn zone most closely resembles that seen in turbidite-hosted (slate belt) gold deposits, such as those in the Lachlan Fold Belt of Australia and the Meguma Group of Nova Scotia. These deposit types are characterized by veins that occur in 1 km, by 8 to 12 km

Plate 1. *Golden Promise prospect (Jaclyn zone): Trench exposure of mesothermal 'sheeted' quartz vein.*

Plate 2. *Golden Promise prospect (Jaclyn zone): Boulder illustrating 'caterpillar track' texture, a feature caused by growth of parallel quartz crystals, between which some of the gold has precipitated. Black circles mark areas of visible gold.*

Plate 3. *Golden Promise prospect (Jaclyn zone): Drill core illustrating spotted, light green (quartz–sericite–carbonate) and dark green (chloritic ?) alteration in fine-grained parts of the host sedimentary rocks to the Jaclyn vein.*

"fields". The veins are typically hosted by faults of short strike length (<1 km) developed parallel to cleavage, and as saddle reefs in large antiformal culminations. The largest deposits generally occur within permeable turbidites, immediately beneath or within carbonaceous shale caprock. Mineralization occurs mainly as coarse native gold within laminated fault-fill quartz veins (bedding parallel thrusts), as well as large-tonnage saddle-reef quartz stockworks in fold hinges, extension veins, and jogs in the laminated vein system. "Ore shoots" occur along the fold hinges, and parallel to fold hinges within the laminated veins. Visible alteration extends up to 10 m from the auriferous veins and consists of white mica, quartz, carbonate, sulphides (pyrite, arsenopyrite, pyrrhotite) and locally albite.

DOME PROSPECT (UTM 658650mE, 5428550mN)

The showing (Figure 2) is located approximately 1.5 km north of the Trans-Canada Highway, immediately east of Appleton. The prospect lies along a prominent topgraphic linear within shale of the Hunt's Cove Formation, a part of the Davidsville Group. Trenching around a poorly exposed outcrop of vein quartz exposed a 3 by 8 m lens of gold-bearing quartz vein (Plate 4), which trends northeast, oblique to the general north-northeast trend of the linear. The vein is a coarse-grained mesothermal structure that is sulphide-poor, and somewhat sinusoidal in shape, suggesting formation in a shear-related dilational zone. On the northwest contact of the vein, a metre-scale, steeply plunging fold nose in the

Plate 4. *Dome prospect: This mesothermal quartz vein appears to be a small 'reef' developed at the nose of a minor fold in Davidsville Group shale. Visible free gold is commonly associated with an apple-green sericite.*

shale suggests that the vein may have formed originally as a minor saddle reef. The southeast margin of the quartz vein contains apple-green sericite as clots and coatings along vein-parallel stylolitic fractures. The visible free gold is generally associated with the sericite. Assay results from this zone (Candente, press release, 2003) include a channel sample of 729 g/t gold over 1.5 m, as well as drillhole intersections of 129 g/t over 1.2 m and 18 g/t over 7.5 m. Numerous other gold occurrences flank the topographic linear in this area, but were not visited.

KNOB PROSPECT (UTM 657350mE, 5425650mN)

This showing occurs as part of a group of greywacke- and shale-hosted, mesothermal quartz veins located in a structurally disrupted part of the Davidsville Group (Plate 5). The prospect is located immediately adjacent to the topographic lineament associated with the Dome prospect. The host rocks strike northeast, dip steeply northwest, and are overturned. Spectacular gold grades have been recovered, e.g., 631 g/t over 0.6 m (Evans, 1996). The mineralization occurs as free gold in quartz veins, and is also associated with adjacent carbonate-altered and arsenopyrite-bearing sedimentary rocks that have given grades of up to approximately 5 g/t (D. Mullen, personal communication, 2004). Much extra trenching has been performed in recent years, and provides excellent exposure for determining vein morphology. Although veining occurs in all rock types, it is best developed in greywacke units, possibly due to the structurally more competent nature of these units.

MUSTANG PROSPECT (UTM 654292mE, 5422859mN)

Auriferous silicified zones in this prospect (Figure 2) are hosted by dark greywacke and shale, and are presumed to be part of the Davidsville Group. The Mustang zone, together with the adjacent Piper zone have also been referred to as the Outflow prospect (Evans, 1996). The silicified zones trend for at least 3 km to the northeast, locally in association with fault zones, and consist of chalcedonic silica in association with comb-textured and crustiform quartz and hydrothermal breccia. Disseminated pyrite is associated with some of the higher grade samples, and needles of possible stibnite have been noted. The best reported assay is 12.23 g/t gold over an unspecified distance (Evans, 1996; Plate 6). The Mustang prospect has been proposed as a possible example of Carlin-style mineralization (Altius Minerals Corporation, press release, 2003). Trace-element geochemistry on pyrites from the prospect (O'Driscoll and Wilton, *this volume*), has shown higher contents of Au, As, Sb and Pb compared to samples from other Newfoundland epithermal and orogenic gold prospects and thus resembles the typical enriched trace-element assemblages (As, Sb, Tl, Hg, and Ba) of Carlin deposits (Arehart, 1996). However, the vein textures are reminiscent of low-sulphidation epithermal mineralization, an interpretation that was also favoured by Evans (1996). Further work is required to adequately discriminate between these possible environments.

Plate 5. *Knob prospect: Dilational quartz veins in Davidsville Group greywacke and shale.*

Plate 6. *Mustang prospect: Silicification and quartz-veining of low-sulphidation epithermal character in siliciclastic sediments of the Davidsville Group.*

JASPEROID SHOWING (UTM 649949mE, 5423566mN)

Prospecting of calcareous units of the Indian Islands Group southwest of Glenwood by Altius Minerals Corporation discovered a float sample of fine-grained, black, silicified rock that returned a value of 0.94 g/t gold (Smith *et al.*, 2003). Subsequent mapping and trenching uncovered the Jasperoid showing, so named because of its apparent similarity to silicified semi-calcareous rocks from the Carlin district of Nevada. The Jasperoid showing is exposed as a 1.5 wide by 5 m long, southwest-trending zone of silicification that was thought by Smith *et al.* (2003), and Barbour and Churchill (2004) to have developed following decarbonatization of the Late Silurian semi-calcareous protolith.

The alteration follows a limestone debris-flow bed containing Silurian corals, brachiopods, crinoids and bryozoans. This bed may have acted as the focus for alteration because of its greater permeability than the bounding rocks. In trench exposures (Plate 7), the debris-flow breccia texture is still discernable in less altered parts of the unit. The silicification is associated with numerous vugs (<1 cm diameter) filled with crystalline quartz, a texture that is indicative of near-surface crystallization. The silicified zone is flanked by laminated, green calcareous siltstone that has been affected by brown carbonate alteration.

Plate 7. *Jasperoid showing: Decalcified and silicified (black matrix) sedimentary breccia of the Silurian Indian Islands Group limestone.*

Immediately adjacent to the Jasperoid showing is a set of quartz veins that have east–west trends perpendicular to stratigraphy. These veins have distinctive epithermal textures in the form of banded colloform quartz and bladed quartz pseudomorphs that have likely replaced calcite or barite. Alteration at this latter location was evidently controlled by a discordant fault or joint that strikes toward the Mustang showing. This suggests that a connection may exist between the two alteration zones and that the stratabound Jasperoid showing alteration may have been fed by fluids utilizing the discordant east–west fault zone. This connection with epithermal systems at what are presumably shallow crustal levels (typically <1 km) does not fit readily with conventional models for Carlin mineralization, which is generally thought to have formed at deeper levels (>2 km; Hofstra and Kline, 2000).

BARITE SHOWING (UTM 649934mE, 5423921mN)

The Barite showing (Figure 2) is located 300 m north of the Jasperoid showing and consists of a sub-vertical vein system of barite and quartz up to 3 m wide and also oriented in an approximately east–west trend perpendicular to bedding in the host Indian Islands Group siltstone. The colloform- and comb-banding of the quartz are indicative of a low-sulphidation epithermal system, a conclusion supported by the local bladed texture of the barite (Plate 8). However, no significant Au has yet been detected at the showing. According to Lake (2004), the barite overprints two earlier phases of silicification; one barren, the other associated with galena and sphalerite, and has a magmatic sulphur-isotope signature (as does the galena sulphur). However, based on oxygen-isotope data from the barite, and on fluid-inclusion trapping temperatures, the fluids responsible for barite precipitation were predominately meteoric in nature, a trait that is held in common with fluids associated with Carlin-type deposits. Barite is also noted to be generally spatially associated with Carlin deposits (Hofstra and Kline, 2000). Grab samples from the showing have returned maximum values of 53 ppb Au, 31 ppb Hg, 15.5% Pb and 278 ppm Ag, and are also anomalous in Zn. As at the Jasperoid area, the textures and elevated base-metal and silver contents may be suggestive of an epithermal, rather than a Carlin-type environment.

ROAD BRECCIA SHOWING (UTM: 650509mE, 5424535mN)

This showing (Figure 2) is located 700 m northeast of the Barite showing. It consists of another east-trending, quartz stockwork and breccia zone having classic low-sulphidation epithermal textures, that cuts at a high angle across Indian Island Group siltstones. The siltstones exhibit brown iron-carbonate alteration adjacent to the stockwork veins (Plate 9). The best reported assay is 307 ppb Au over 1.0 m (Barbour and Churchill, 2004). An unaltered, chilled, gabbro dyke is located 10 m to the south of the breccia zone. It is being dated to constrain the age of mineralization.

Plate 8. *Barite zone showing: Bladed texture of barite in this area may be indicative of precipitation in an epithermal environment.*

Plate 9. *Road Breccia zone showing: Looking west at chalcedonic vein-swarm, showing orange dolomitic alteration of the host Indian Islands Group calcareous siltstone. Bedding strikes north, perpendicular to the vein.*

CLARKS BROOK EAST SHOWING (UTM 642399mE, 5407640mN)

The Clarks Brook East showing (Figure 2) occurs as locally pyritiferous, vuggy quartz veinlet stockwork associated with silicification in what appears to be an incipient tectonic breccia of Indian Islands Group green siltstone (Plate 10). The textures are again indicative of low-sulphidation epithermal-style mineralization. This newly discovered prospect has returned anomalous gold in samples mostly from nearby boulders. The best result was 24.5 g/t Au (Barbour and Churchill, 2004). Recently, a value of 6.89 g/t gold has been returned from an outcrop sample (Altius Mineral Corporation, personal communication, 2004). Very little work has been performed on this occurrence.

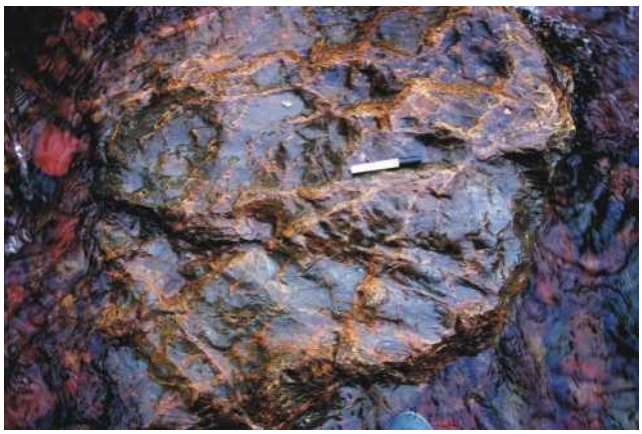

Plate 10. *Clark's Brook East showing: Auriferous vuggy quartz veinlets of low-sulphidation epithermal character are present in Indian Islands Group siltstones.*

O' REILLY SHOWING (UTM 635428mE, 5399897mN)

This showing (Figure 2) consists of an east–northeast-trending zone of intense silicification and quartz veining in green siltstone or fine-grained sandstone. The host rock is likely part of the Indian Islands Group. Textures include moderately vuggy quartz and chalcedonic silica (Plate 11). The southern flank of the zone contains a black, silica-sealed fault breccia, which returned a best channel assay of 5.2 g/t gold over 1.0 m. A value of 12.98 g/t gold was also obtained from a grab sample (Smith *et al.*, 2003). The alteration has been traced over a 3-km-strike length and includes the O'Reilly extension showing 2 km to the northeast, which has returned values of up to 6.35 g/t gold from grab samples (Smith *et al., op. cit.*).

Plate 11. *O'Reilly showing: The banded chalcedonic quartz matrix to a tectonic siltstone breccia in probable Silurian rocks, demonstrates the epithermal nature of this showing.*

Plate 12. *Contact showing: The Mount Peyton Intrusive Suite granite is argillitized and cut by chalcedonic quartz veining of low-sulphidation epithermal type. Mineralization consists of gold and silver in association with minor pyrite and base-metal sulphides.*

CONTACT SHOWING (UTM 635442mE, 5400448mN)

This showing is located 400 m within the eastern (granite) part of the Mount Peyton Intrusive Suite, 400 m from the contact. The granite has undergone local argillic alteration and is cut by chalcedonic silica veins (Plate 12). It also contains minor pyrite and base-metal-sulphide mineralization. The prospect has returned assays of up to 1.2 g/t gold, up to 13.01 g/t silver, and up to 0.82% copper, as well as anomalous Pb, Zn, As, Sb and Mo from boulder and outcrop samples (Barbour and Churchill, 2004). Chalcedonic veining also crosscuts the adjacent contact aureole of the granite. This, coupled with similar veining at the nearby O'Reilly showing 600 m farther south, suggests the operation of a shallow-level hydrothermal event that affected all three areas. This is supported by the fact that all three areas occur within a single, broad gold-in-soil anomaly (Barbour and Churchill, 2004).

BEAVER BROOK ANTIMONY MINE AREA (UTM 629837mE, 5395493mN)

Recent delineation drilling at the dormant Beaver Brook Mine by VVC Exploration Corporation has been undertaken as part of a program to better define the resource prior to possible resumption of mining. The best intersection from this drill program has been in drillhole 97-096, which has given a value of 5.03% antimony over 30.7 m, (B. Willet, personal communication, 2004). The mineralization is hosted by the Davidsville and Indian Islands groups.

The mineralization intersected in the recent drilling program is hosted by deep-water argillaceous sedimentary rocks that contain local debris-flow beds containing a variety of exotic fragments. The presence of centimetre-scale clasts of limestone containing coral, crinoid and bryozoa fragments indicates a Silurian age (W.D. Boyce, personal communication, 2004) and suggests that the host rocks are part of the Indian Islands Group. The debris flows also contain structurally disrupted clasts of strongly altered and locally mineralized leucoxene-bearing gabbro, suggesting derivation from a mélange zone. Mélange is associated with the Dog Bay Line to the northeast (Duder and Garden Point mélanges, Williams *et al*., 1993) but has not yet been traced this far to the southwest.

The mine mineralization occurs within two, main, closely spaced mineralized fault zones that are believed by the mine geologists to be offsets of one original zone. These trend northeast and have a moderate southeast dip. Athough subparallel to the strike of the host-rock stratigraphy, the veins are somewhat discordant when seen in section view. The mineralization occurs mostly as massive stibnite within the fault-related veins, and as vug fillings within dilational fractures adjacent to and within the fault zones. Stibnite occurs alone, but more typically with carbonate and only rarely with quartz. Later unmineralized faults are present, some of which truncate the ore intersections.

Stibnite mineralization has also been uncovered at the nearby Beaver Brook Central zone trench (the former 'Hunan' prospect) where it is hosted by quartz-rich greywackes that are associated with Caradocian graphitic graptolitic shale and chert of presumed Ordovician age (Williams and Tallman, 1995) and probably part of the Davidsville or Badger groups.

The stibnite mineralization is exposed in a stripped area of about 50 by 75 m located about 1 km west of Cooper Brook. The host rocks consist mainly of sandy, quartz-rich

greywackes interbedded with shale and local black chert. The mineralization again occurs in fault breccias and shear zones (Plate 13) confined almost exclusively to the more brittle greywacke and cherty units. In dilations adjacent to main structures, the veins contain vuggy quartz in association with iron-carbonate (or dolomite?) and stibnite (Plate 14). There is also a significant abundance of chlorite–pyrite veining and locally a rare apparent co-existence of pyrite and stibnite, although these minerals also occur in separate (i.e., unrelated) vein phases in the same outcrop. Structures in the stripped area consist mainly of brittle dilation zones that also display bedding-parallel and oblique brittle–ductile shearing. There is little evidence of folding at the outcrop scale, although the presence of abundant quartz veins perpendicular to bedding may suggest proximity to a large, open fold nose.

Plate 13. *Beaver Brook (Hunan or Central zone) antimony prospect: Quartz–carbonate veins thought to be of epithermal character, crosscut fault-brecciated sedimentary rocks of Davidsville or possibly Badger groups.*

The textures of the quartz (Plate 15) and stibnite veining in the Beaver Brook area bear marked similarity to that seen in the low-sulphidation, epithermal gold occurrences to the northeast. They also share the same host rocks, have a common Sb–Au association, and both are adjacent to the Mount Peyton Intrusive Suite.

Plate 14. *Beaver Brook (Hunan or Central zone) antimony showing: Fault-brecciated greywake and siltstone fragments are rimmed by crustiform quartz and vugs that are filled by later iron-carbonate and stibnite. The veins indicate an epithermal setting for the stibnite mineralization.*

Plate 15. *Beaver Brook (Hunan or Central zone): Quartz vein stockwork of epithermal style suggests a possible genetic relationship between gold and antimony mineralization at the regional scale.*

HORWOOD QUARTZ VEIN BRECCIA (UTM 678170mE, 5479797mN)

An extensive quartz-vein breccia is exposed in the town of Horwood on the east shore of Dog Bay (Figure 2). The veins display multiple phases of chalcedonic and crustiform quartz veining disrupted by several phases of hydrothermal brecciation and, as such, appear to be part of a low-sulphidation epithermal system. To the author's knowledge, nothing has been reported concerning the possible gold content of this zone. The quartz vein zone (Plate 16) occurs directly

Plate 16. *Horwood Quartz Vein Breccia: Crustiform quartz veins and hydrothermal breccia of low-sulphidation epithermal character. The breccia cuts silicified (Ordovician?) graphitic slates and mylonites of the Dog Bay Line.*

on Dog Bay Line, where it cuts sulphidic and graphitic slate that is mapped as part of the Duder mélange (Williams *et al*., 1993). The veins clearly crosscut and brecciate the mylonitic foliation associated with the Dog Bay Line. This indicates that the Horwood quartz-vein system is, therefore, one of the youngest features in the area and that at least some of the epithermal activity in the area postdates the Dog Bay Line and is of Late Silurian or younger age.

TIBBEY'S POINT SHOWING (UTM 683714mE, 5468859mN)

This occurrence (Figure 2) consists of a thin (<30 cm-wide), steeply south-dipping quartz vein (Plate 17), which is locally deformed and appears to trend parallel to the axial planar cleavage in the folded shale to sandstone beds of the Ordovician Carmanville mélange. The quartz vein is polymetallic, containing pyrite, chalcopyrite, arsenopyrite, stibnite and possible boulangerite (G. MacVeigh, personal communication, 2004). The wallrock contains pyrite and one grab sample from the vein has given an assay of 47.39 g/t gold (D. Ledrew, personal communication, 2004). Previous drilling intersected 9.98 g/t Au over 1.15 m.

BUSSEY'S (WINGS) POINT SHOWING (UTM 683588mE, 5467590mN)

This showing (Figure 2), which is only visible at low tide, extends for more than 50 m along strike and consists of thick, sheeted quartz veins (Plate18) that are locally sheared and boudinaged. The host rock is folded Davidsville Group greywacke to shale, which strikes east-northeast and has variably north to south dips due to folding. Cleavage dips moderately to steeply to the south and is probably axial planar to the folds. The quartz veins are oriented approximately parallel to the cleavage. The immediately adjacent wall-

Plate 17. *Tibbey's Point showing: This deformed polymetallic quartz-vein of mesothermal type trends subparallel to the axial planar cleavage of local folds.*

Plate 18. *Bussey's Point showing: A foliated and boudinaged mesothermal quartz vein system trends sub-parallel to the axial planar cleavage of local folds.*

rock and nearby beds of greywacke are altered and contain up to 10 percent disseminated arsenopyrite and pyrite. To date, the showing has returned only anomalous gold values.Veining has been interpreted to extend for up to 2 km to the Ledrew showing area (D. Ledrew, personal communication, 2004) based on prospecting results.

LEDREW SHOWING (UTM 681995mE, 5466610mN)

This showing consists mainly of a low-grade quartz vein hosted in faulted greywacke and shale of the Davidsville Group. The area hosts abundant widespread arsenopyrite patches in wallrock shale that extend hundreds of metres across strike from the showing. It has been suggested (*see above*) that this occurrence is a direct along-strike extension of the Bussey's Point vein. Grab samples have yielded up to 11.65 g/t gold and channel samples have given up to 1.09 g/t over 1.00 m.

TITAN SHOWING (UTM: 675730E/5465523)

The Titan showing (Figure 2) consists of quartz-vein systems associated with orange-brown iron-carbonate alteration hosted by a gabbro dyke (Plate 19) that intrudes laminated and crossbedded sandstones mapped as Indian Islands Group (Currie and Williams, 1995). The veins are of mesothermal character and have given high-grade drill results including 10.22 g/t gold over 3.35 m (Crosshair Exploration and Mining Corporation, press release, September 9, 2004). A sample of this gabbro has been collected to constrain the age of intrusion and mineralization.

Plate 19. *Titan showing: Mesothermal quartz veins in a gabbro dyke are associated with intense brown iron-carbonate alteration. The dyke intrudes siliciclastic rocks of the Indian Islands Group.*

STARTRACK TREND (PROSPECT) (UTM 694841mE, 5417330mN)

This prospect of parallel quartz veins intrudes psammitic to pelitic metasedimentary rocks of the Gander Group (Figure 2). The prospect consists of a number of mesothermal-type quartz veins exposed in a series of trenches (Plate 20). The quartz veins most enriched in gold are hosted within quartz veins that follow small, northwest-dipping thrusts that are axial planar to F_3 folds (Rubicon Minerals Corporation, personal communication, 2004). The veins have returned assays of up to 20.7 g/t gold over 0.6 m in channel samples, and 256.1 g/t in grab samples. Gold appears to be associated directly with arsenopyrite and is associated with some sericitic wallrock alteration.

STALLION TREND (PROSPECT) (UTM 696580mE, 5415680mN)

The Stallion prospect quartz veins are located 800 m east of the StarTrack trend. They are exposed in a series of trenches and are hosted by the Gander Group, which here consists predominantly of psammites and pelites, but also contains some cordierite schist, calcareous semipelite, graphitic pelite and metachert. The most northerly trench has exposed a unit of interlaminated semipelite and limestone, which is correlated with the Indian Bay–Big Pond Formation. Processing of the limestone for conodonts was unsuccessful.

Plate 20. *StarTrack showing: Thin mesothermal quartz veins (parallel to hammer) are developed along F_3 fold axial planes and associated faults. The host rocks are psammites of the Gander Group. The veins contain arsenopyrite and fine visible gold.*

In contrast to the StarTrack trend, the quartz veins are distinguished by multiple generations of chalcedonic silica veining and hydrothermal brecciation and locally the veins display spectacular cockade texture with cavities retained between fragments (Plate 21). The veins are, therefore, clearly of low-sulphidation epithermal nature. In places, they also contain accessory green fluorite and lesser stibnite. The veins have interesting gold grades of up to 3.02 g/t over 0.6 m, (Rubicon Minerals Corporation, personal communication, 2004).

The number and extent of the veins that have been discovered at both the StarTrack and Stallion prospects is impressive. Given the poorly exposed nature of the surrounding area there appears to be considerable potential for further discovery.

DISCUSSION

Most of the showings investigated so far are associated with relatively deeply formed (ca. 5 km or greater), late-orogenic quartz veins that are associated with shear zones or folds. They may have associated wallrock alteration and mineralization (e.g., arsenopyrite, pyrite). Prospects such as the Golden Promise, Knob, Dome, StarTrack and Titan prospects are examples of this broad class. A less common

Plate 21. *Stallion showing: Cockade- and crustiform-textured quartz forms rims around altered rock fragments in a hydrothermal breccia bounded by banded, chalcedonic silica veins. Note the open space retained between fragments. The textures indicate a low-sulphidation epithermal setting.*

group of Au occurrences that has also been documented is that of the very shallow depth (ca. <1 km), low-sulphidation epithermal environment. This is characterized by fine grained silicification, development of massive and banded chalcedonic veining, bladed crystals (quartz after calcite or barite), multiple veining textures, and locally cockade-textured breccias. Prospects such as Stallion and Mustang are similar in these respects to other low-sulphidation epithermal prospects documented in the northeastern Dunnage Zone, e.g., the Aztec, Rolling Pond and Moosehead prospects. The Beaver Brook Mine stibnite mineralization, although associated with faulting, also exhibits textures indicative of an epithermal environment.

The suggestion that the predominantly Silurian rocks of the Botwood basin have potential for Carlin-type gold mineralization has led to a boom in staking and exploration activity in recent years. Among other criteria, this model advocates gold deposition at depths intermediate to those previously described. It is predicated on the presence of semi-calcareous units of the Indian Islands Group that have undergone partial dissolution and later silicification (to produce jasperoid). Examples of this are seen in the silicified limestone breccia and associated barite of the Jasperoid and Barite zone prospects. The model is supported by the presence of 'toxic-element suite' trace-element pyrite geochemistry (O'Driscoll and Wilton, *this volume*) and by the meteoric nature of the alteration fluids at the Barite showing (Lake, 2004). Whilst the rich nature of the Carlin-trend deposits certainly makes this model attractive for exploration, and its continued application is encouraged, there are difficulties in locally distinguishing the effects of possible Carlin-style mineralization from the low-sulphidation epithermal systems that have affected the same rocks. Further work is required to adequately discriminate between these two environments. Regardless of the precise deposit model that is eventually chosen, there is abundant evidence that the Silurian rocks of the "Botwood basin" have great potential for further gold discoveries.

With respect to the Beaver Brook antimony mineralization, the discovery of Silurian fossil fragments in sedimentary debris flows (or mélange) demonstrates that the mineralization is Silurian or younger in age and affects a mixture of rocks that belong to the Davidsville or Badger groups, and the Indian Islands Group.

The disposition of epithermal gold and antimony occurrences in the Silurian rocks (the 'Botwood basin') that surround the multiphase Mount Peyton Intrusive Suite has invited speculation that it was Mount Peyton magmatism and related hydrothermal activity that generated the epithermal systems (e.g., O'Driscoll and Wilton, *this volume*). However, the gold mineralization in epithermal systems straddles the Dog Bay Line, the interpreted "terminal Iapetus suture" (Williams *et al.*, 1993), a structure that is probably younger than the Mount Peyton Intrusive Suite. Also significant in this respect is the Horwood epithermal system, which cuts the mylonitic fabrics of the Dog Bay Line. This strongly suggests that at least some of the low-sulphidation epithermal mineralization is Late Silurian or even Devonian in age and probably unrelated to the Mount Peyton magmatism. To date, no evidence of Mount Peyton intrusive activity has been found east of the Dog Bay Line. There are, however, some mafic dykes (a mineralized one from the Titan prospect and one unmineralized from the Road Breccia showing), which have been sampled for U–Pb geochronology. These may provide more precise constraints on the timing of gold mineralization in the Indian Islands Group and the relationship of mineralization to the Mount Peyton Intrusive Suite.

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