HIGH-SULPHIDATION, EPITHERMAL-STYLE HYDROTHERMAL SYSTEMS IN LATE NEOPROTEROZOIC AVALONIAN ROCKS ON THE BURIN PENINSULA, NEWFOUNDLAND: IMPLICATIONS FOR GOLD EXPLORATION

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ABSTRACT

The late Neoproterozoic Avalonian succession of the Burin Peninsula is host to one of the largest (and least-explored) metamorphosed auriferous epithermal systems in Canada. Extensive zones of advanced argillic alteration, containing the high-sulphidation alteration assemblage pyrophyllite–alunite–quartz–kaolinite–hematite–rutile–lazulite, are associated with discrete areas of massive and, locally, vuggy silicic alteration, containing gold, and anomalous concentrations of copper, arsenic and/or antimony. On the northern Burin Peninsula, two regional belts of volcanic-hosted epithermal alteration are recognized (viz., eastern and western); these are sited peripheral to, and on opposing sides of, the plutonic suites at the anticlinal core of the peninsula. Together they comprise the Hickey's Pond–Point Rosie alteration system, which has a strike length in excess of 100 km. The best-known gold-bearing zones in this system are the Hickey's Pond and Stewart prospects.

The alteration and gold mineralization occurs in deformed greenschist-facies volcanic rocks of the 590 to 565 Ma Marystown Group. Spatial and genetic relationships exist between mineralization and the eastern margin of the Swift Current Granite and that of related intrusions along strike, particularly in the eastern alteration belt. Alteration in the western belt is sited preferentially along the boundary between felsic volcanic rocks and a regionally extensive, arenaceous siliciclastic sed-imentary sequence. Chronological relationships indicate that the epithermal-style alteration formed prior to the main phase of Siluro-Devonian ductile thrusting.

Similarly altered rocks of equivalent age and stratigraphic setting, carrying significant gold and arsenic mineralization, reappear on the southern Burin Peninsula, in and around the Kelstone property. The occurrence of dumortierite-pyrophyllite-andalusite-bearing hydrothermal alteration, farther to the southwest at Stroud's Pond, may be related to high-sulphidation alteration and – potentially – mineralizing events of similar age.

The nature of the host rocks, the style of alteration, the anomalous gold content of advanced argillic alteration, and the local presence of high-grade gold mineralization, indicate that there is definite potential for significant, high-sulphidation (and related porphyry Cu–Au) style mineralization. Newly discovered, high-grade, breccia-hosted gold mineralization associated with intrusive rocks, north of the Hickey's Pond–Point Rosie system at Goobies, coupled with the recent identification of extensive silica alteration in other parts of the Burin Peninsula, further underscore the region's importance as an auriferous metallogenic belt, and highlight the hitherto little-recognized gold potential of its plutonic suites. The analogies with the Avalonian Hope Brook gold deposit, in terms of both the nature and age of the host rocks and style of the hydrothermal system, further supports such potential. Most of the known gold-bearing prospects on the Burin Peninsula remain untested at depth.

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INTRODUCTION

Newfoundland's Burin Peninsula is located within the eastern margin of the Appalachian orogen, at the northeast termination of the Appalachian Avalonian belt (O'Brien et al., 1996, 1998). The late Neoproterozoic geology of the Burin Peninsula, like that of the larger Avalonian belt, records the protracted and episodic development of subaerial volcano-plutonic arcs and marine to terrestrial sedimentary basins of peri-Gondwanan paleogeographic affinity, in the time period between 760 and 540 Ma (O'Brien et al., 1996). As is the case elsewhere in the Avalonian belt, the Neoproterozoic volcanic successions of the Burin Peninsula are capped unconformably by a transgressive quartz-arenite-shale sequence of Cambrian age, containing Acado-Baltic faunal assemblages (e.g., Butler and Greene, 1976). The Neoproterozoic rocks were inhomogeneously deformed with the early Paleozoic cover during low-grade tectonothermal events of Siluro-Devonian age, related to Salinic and Acadian orogenesis in the internal part of the Appalachian belt (e.g., Dallmeyer et al., 1983; Dunning et al., 1990; S. O'Brien et al., 1991). The Neoproterozoic and Cambrian rocks were unconformably overlain by terrestrial volcanic and siliciclastic rocks of Late Silurian and Early Devonian age (O'Brien et al., 1995). Deposition of the mid-Paleozoic strata was coeval with the emplacement of large granitic plutons along the western segment of the Newfoundland Avalonian belt, including the western Burin Peninsula.

Many of the hydrothermally altered rocks on the Burin Peninsula are associated with widespread Neoproterozoic magmatic activity that peaked between ca. 590 and 560 Ma. At that time, extensive magmatic arcs developed along the entire length and width of the larger Appalachian Avalonian belt, in arc, or arc-adjacent and continental extensional settings. Volcanism was in part coincident with the development and infilling of marine, deltaic and terrestrial siliciclastic sedimentary basins (O'Brien et al., 1998 and references within). Magmas were typically emplaced into high crustal levels, and were erupted as subaerial, caldera complexes. Cooling and degassing of the high-level plutons resulted in the establishment of large-scale, near-surface hydrothermal convective systems in the volcanic carapace. The resultant epithermal alteration and associated acid leaching was locally accompanied by the deposition of gold, silver, copper, arsenic, antimony and locally zinc, in a variety of epithermal volcanic and subvolcanic settings.

The following account summarizes several such late Neoproterozoic hydrothermal alteration systems, and includes a detailed description of the nature and chemistry of high-sulphidation style alteration facies at the Hickey's Pond gold prospect of the northern Burin Peninsula. Related alteration zones from the eastern (Stewart prospect, Point Rosie prospect) and western (Monkstown Road prospect) belts of the larger Hickey's Pond–Point Rosie alteration system are briefly summarized. A short description of more recently discovered alteration and precious- and base-metal mineralization on the southern Burin Peninsula (Kelstone property) is also included, together with a note on the alteration at Stroud's Pond.

NEOPROTEROZOIC GEOLOGICAL FRAMEWORK OF THE BURIN PENINSULA

Geologically, the Burin Peninsula represents a broad, regionally flexured anticlinorium, cored by variously deformed subaerial volcanic and coeval plutonic rocks (see O'Brien et al., 1981; 1990; Figure 1). The Neoproterozoic volcano-plutonic core of the peninsula, represented by the 590 to 565 Ma Marystown Group and the intrusions emplaced into it, is flanked to the east by the upward-shoaling marine to terrestrial volcano-sedimentary succession of the Neoproterozoic Musgravetown Group, and the underlying marine turbidites of the 620 Ma (and later) Connecting Point Group (O'Driscoll and Muggeridge, 1979; O'Brien and Taylor, 1983; Dec et al., 1992). Farther south, the Marystown Group is juxtaposed to the east with the ca. 760 Ma (and earlier) Burin Group, an oceanic volcano-plutonic series containing distinctive, stromatolitic carbonate olistostromes (Strong et al., 1978a,b). To the west and northwest, the Marystown Group is overlain by the ca. 570 to 545 Ma Long Harbour Group, a thick succession of dominantly felsic volcanic rocks of alkaline to peralkaline affinity (Williams, 1971; O'Brien et al., 1995). These rocks pass conformably upward, through formations of shallow marine, subaerial volcanic and terrestrial clastic rocks, into fossiliferous Cambrian strata (Williams, 1971; O'Brien et al., 1984).

The most extensive of the volcanic successions, and the host to most of the epithermal alteration on the Burin Peninsula, is the Marystown Group (Strong et al., 1978a,b), a lithologically diverse complex of greenschist-facies subaerial flows and volcaniclastic rocks, the products of protracted and episodic, large-scale caldera-forming eruptions. The Marystown Group exhibits a continuum of compositions from basalt, through andesite and rhyodacite, to rhyolite, all of variable calc-alkaline and tholeiitic affinity (e.g., Hussey, 1979; O'Brien et al., 1990, 1996). Clastic and epiclastic rocks separate those rocks from an upper bimodal suite of late Neoproterozoic continental, alkaline basalts and high-silica rhyolites. The Marystown Group has been intruded by coeval, high-level plutons of hornblende-biotite granite, diorite and gabbro, which form part a broad semicontinuous plutonic belt extending along the northern half of the Burin Peninsula. These include the 580 to 570 Ma Swift Current Granite and the similar, and presumed coeval, Cape Roger Mountain and "Burin Knee" granites (O'Brien and Taylor, 1983; O'Brien et al., 1984).



Figure 1. Generalized geological map of the Burin Peninsula and surrounding areas, southern Newfoundland (modified from O'Brien et al., 1996; PSF = Paradise Sound Fault).

REGIONAL SETTING OF THE HIGH-SULPHIDATION ALTERATION SYSTEMS

Auriferous epithermal alteration is best preserved in the Hickey's Pond–Point Rosie alteration system (Figure 2). This bipartite zone of high-sulphidation epithermal alteration can be traced discontinuously along strike, between Swift Current and Point Rosie, a distance in excess of 100 km. Altered rocks typically display some or all of the advanced argillic alteration assemblage pyrophyllite–alunite–quartz–kaolinite–hematite–rutile–lazulite. Alteration in this region is spatially associated with either the eastern margin of the major granitoid suites or the contact with the westerly adjacent (overlying?) unit of arenaceous volcanogenic clastic rocks. Highest precious- and base-metal values are associated with vuggy silica alteration within larger areas of quartz–alunite–hematite alteration associated with these contacts. In many cases (e.g., Hickey's Pond prospect), the superimposed strain is high, and the alteration is complexly deformed. In most cases, alteration is clearly pretectonic with respect to this regional deformation. The geological setting, the mineralogy of alteration, the chemical signature of altered rocks, and the nature of preciousand base-metal mineralization within the Hickey's Pond–Point Rosie alteration system are all consistent with high-sulphidation, epithermal-style alteration (e.g., Heald *et al.*, 1987; Hedenquist, 1987).

Farther south on the Burin Peninsula, south of the Cape Roger Mountain Granite, extensive areas of silica alteration and gossanous silica–sericite–pyrite alteration, with locally elevated gold values, occur in the area between Bay de l'Eau



Figure 2. Distribution of some of the principal rock units and epithermal alteration systems on the Burin Peninsula. Coloured inset map shows the distribution of the eastern and western belts of the Hickey's Pond–Point Rosie alteration system.

Brook and Boat Harbour. Similar alteration reappears in the Baine Harbour area, where it is spatially associated with an extensive quartz–feldspar porphyry unit; the latter unit continues along strike toward Marystown. At Marystown, gold, arsenic and copper mineralization (Kelstone property) occurs within felsic and mafic rocks of similar age and facies as those hosting the Hickey's Pond and related prospects. Unlike the latter area, intrusive rocks are not exposed at the Kelstone property, and the overall degree of superimposed strain is relatively low. Farther south, at Stroud's Pond, the same volcanic rocks are host to dumortierite-andalusite-pyrophyllite alteration (Van Alstine, 1948).

On the northernmost Burin Peninsula, near Goobies, magmatic rocks that may be coeval with the Marystown volcanic succession contain significant diatreme-hosted gold, arsenic and copper mineralization (Avalon property; NDT press release, January 7, 1999). Neoproterozoic plutons elsewhere in the belt are locally altered; cogenetic quartz–feldspar porphyry contains a number of small, but potentially significant copper occurrences.



Figure 3. Regional geological setting of the Hickey's Pond prospect and associated high-sulphidation alteration zones around the southern part of the Swift Current Granite (from Huard and O'Driscoll, 1986).

HICKEY'S POND PROSPECT

The best-known gold showing of the northern Burin Peninsula occurs at Hickey's Pond, approximately 14 km southwest of the community of Swift Current. The presence of extensive specular hematite mineralization in association with alunite-bearing rocks at Hickey's Pond was known since the 1930s, when the property was initially examined and promoted as a possible source of iron (Dahl, 1934; Bainbridge, 1934; Howland 1938, 1940). Hussey (1978) recognized pyrophyllite at Hickey's Pond, and suggested that the alunite–pyrophyllite assemblage indicated economic potential for precious metals. The gold potential of these rocks was subsequently confirmed by sampling during geological and geochemical surveys by government (O'Driscoll, 1984; O'Driscoll and Huard, 1984) and industry (e.g., McKenzie, 1983; Dimmell and MacGillivray, 1989). Alteration and mineralization occurs in high-strain, greenschist-grade pyroclastic rocks of the Marystown Group (ca. 572 Ma, J. Ketchum, written communication, 1998), which are overthrust (from the west) by deformed and largely unaltered granite belonging to the Swift Current Granite. Other zones of similar alteration that lie immediately on-strike of the Hickey's Pond prospect include the Headwaters and Eric showings to the north, and the Chimney Falls and Tower showings, to the south (*see* Huard and O'Driscoll, 1986; Huard, 1990; Figure 3). In the early 1980s, BP-Selco carried out magnetic, VLF-EM and IP surveys, and subsequently drilled 5 holes to test the alteration zone exposed at Hickey's Pond (e.g., McKenzie, 1983). More detailed studies of the hematite occurrences and related hydrothermal alteration on the northern Burin Peninsula were carried out following the BP-Selco work: Huard and O'Driscoll (1986); Huard (1990). The property reverted to the Crown in 1988, after which it was staked by Lacana (International Corona Corporation). Corona Corporation's assessment included resampling of BP-Selco core, further surface sampling and the drilling of 4 new holes. Gold values up to 12.4 g/t over 1.2 m were returned from channel samples by Corona Corporation (Dimmell and MacGillivray, 1989). The Hickey's Pond prospect was transferred to Krinor Resources Inc. in 1991.

HYDROTHERMAL ALTERATION

Several lithologically distinct components of a larger high-sulphidation epithermal system are exposed over a 125 by 225 m area on a peninsula in Hickey's Pond (Hickey's Pond prospect: Huard and O'Driscoll, 1986; Huard, 1990). Mapping done during this study has identified seven separate alteration units (Figures 4 and 5), the most economically significant of which are zones of massive silicic alteration (Unit A). These are characterized by buff to beige, generally massive silicic rocks, largely devoid of sulphides. These rocks contain up to 97.7 percent SiO₂, and are thus strongly depleted in most major elements other than silica and titanium. The massive silica zone carries anomalous Au, ranging between 0.3 and 1.1 g/t. With the exception of rare grey quartz phenocrysts and fine-grained disseminations of brown rutile, the rocks are typically featureless. Narrow veinlets of grey silica locally crosscut the massive silica. Rarely preserved relict shard- and pumice-like textures reveal the pyroclastic nature of the altered felsic host. Massive silica occurs within a zone of variably pyritic quartz-alunite-rutile rocks that pinches out toward the north. The silicic rocks are injected by deformed, latehydrothermal white quartz veins containing large platy aggregates of crystalline specular hematite, together with finely crystalline pyrophyllite; these typically appear to be barren.

The massive silicic zones locally envelope small (1 by 3 m) discontinuous zones (≤ 1 by 3 m) of sulphide-free vuggy silica (Plate 1), containing between 80 and 96 percent SiO₂. Grab samples of the vuggy silica material have returned assays of 15.4 g/t Au, 15g/t Ag, 0.29% Sb and 0.28% As (Table 1). At least one small discontinuous pod of sulphide-rich quartz–alunite–tennantite rocks is locally preserved in the massive silicic zone. It is auriferous, yielding assays up to 7.5 g/t Au, and contains up 109 g/t Ag, 1.5% As, 3.4% Cu, and 0.8% Sb.

(Unit G) are developed in the northern end of the main unit of massive silicic alteration (Plate 2). Black, fine-grained specular hematite and quartz invades and brecciates buff, massive (and not vuggy) silicic-altered material. The resulting breccia contains angular to rounded and locally tabular clasts that vary from a few millimetres up to 6 cm in maximum dimension. Gold grades within the hematite breccia vary independently of grain size, silica content or degree of brecciation. Gold values up to 5.4 g/t Au (Huard, 1990) have been described from the breccias (Table 1). The silicahematite breccias also contain selvages of red-brown pyrophyllite and/or kaolinite along foliation planes, as well as pink alunite aggregates. Continuous zones of quartz-alunite-pyrite-rutile alteration (Units B1 and B2) are developed adjacent to the massive silicic alteration (Plate 3). As is the case with the silica zone on surface, the quartz-alunite-pyrite rocks pinch out to

Zones of hematite-rich auriferous hydrothermal breccia

The silica and surrounding quartz-alunite-pyrite zones both lie within a unit of dark grey to interlayered buff-brown and grey, banded quartz-hematite-alunite alteration (Plate 4), which occupies most of the surface exposure on the Hickey's Pond peninsula. Small, isolated, centimetre- to metre-scale pods of quartz-alunite-pyrite material occur within this banded hematite-rich rock, and contain up to 2.36 g/t Au. The hematite content increases toward the west-northwest, where massive to semimassive hematite schists are present. In the same area, vuggy quartzhematite-rich rocks are developed on a small scale, and contain up to 1.36 g/t gold (Table 1). Drillhole data indicate that the host rocks of at least part of the hematite-rich zone have a mafic composition. The banded hematite rocks pass gradationally into a zone of quartz-alunite ± lazulite alteration at the eastern edge of the alteration zone (Unit E). Unit D (Figure 4) represents the transition between these two units. Alunite-bearing rocks are bounded to the east by quartzsericite schists (Unit F), which may represent an alteration facies that developed distal to the hydrothermal system's core.

DEFORMATION

the north.

The hydrothermally altered succession at Hickey's Pond includes some of the most penetratively deformed rocks on the Burin Peninsula. The altered rocks are characterized by a folded, southwest–northeast-trending and steeply northwest-dipping S foliation, which locally contains a moderately to steeply southwest-plunging stretching lineation. The alunite–pyrophyllite–hematite–quartz assemblage is elongated along the S₁ foliation. This penetrative S₁ foliation is locally axial planar to isoclinal F folds that



Figure 4. Distribution of hydrothermal alteration facies at the Hickey's Pond prospect, Burin Peninsula.



Figure 5. Schematic representation of the distribution of high-sulphidation alteration facies at Hickey's Pond, showing the location of gold mineralization.



Plate 1. Gold-bearing vuggy silica alteration, Hickey's Pond prospect.

plunge steeply to the southwest and deform a layering defined by bands of advanced argillic alteration minerals, transposed along S_1 . On structural grounds alone, the hydrothermal alteration assemblage is thus early to pre-D₁

deformation. The S1 foliation is composite and is associated with a local CS-type fabric indicating a reverse sense of motion compatible with that along the adjacent Hickey's Brook Fault. A similar reverse sense of motion on northeast-southwest shear zones is common throughout the region. The D1 structures are deformed by open, moderately to steeply northeast-plunging F2a folds and well-developed, small-scale, moderately to shallow southwest-plunging F_{2b} folds with southeast vergence (Plate 5); the respective chronology of the two sets of folds has yet to be determined. The distribution of the alteration units in plan is controlled by the moderately to steeply northeast-plunging F_{2a} folds. The southwest-plunging F2b folds affect the distribution of the alteration units in section view. The overall strain at Hickey's Pond increases to the west, with increasing proximity to the Hickey's Brook Fault.

DISTRIBUTION OF GOLD

The highest gold grades at Hickey's Pond occur in sulphide-poor vuggy silica rock within the zones of massive silicic alteration. Samples from the areas of vuggy silica



Plate 2. Gold-bearing specular hematite-rich breccia (Unit G), in which massive, buff and grey silica alteration has been hydrothermally brecciated by specular hematite and silica, and cut by deformed hematite–alunite-bearing late-hydrothermal quartz veins. Hickey's Pond prospect.

returned assays ranging from 1.1 to 15.4 g/t Au, and up to 0.29 % Sb and 0.28 % As. Significant gold (4 to 5 g/t) also occurs where silica-altered material has been intruded by hematite–quartz hydrothermal breccia. Elsewhere, massive silica (without sulphides) carries anomalous gold values up to 1.1 g/t Au. The quartz–alunite–pyrite zone is anomalous in gold, yielding values between 0.3 and 0.6 g/t. Higher grades (\leq 2.4 g/t Au) occur in mineralogically similar, metrescale pods within the quartz–hematite–alunite zone.

The very strong association of vuggy silica and gold seen at Hickey's Pond is typical of high-sulphidation epithermal systems (e.g., Arribas, 1995), as is the anomalous concentration of arsenic and antimony. The lack of significant amounts of mineralized rock at surface is thus predictable, given the paucity of vuggy silica material. The presence of elevated gold values in quartz–alunite–pyrite



Plate 3. *Quartz–alunite–pyrite–rutile alteration zone (Unit B2), Hickey's Pond prospect.*



Plate 4. Hematite–alunite–quartz alteration zone (Unit C), displaying F₁ fold and S₁ transposing hematite-rich bands at a shallow angle, Hickey's Pond prospect.

rocks at surface should be seen as a positive factor, indicative of anomalous alteration that may potentially lie proximal to larger bodies of mineralized vuggy rock at depth.

It is noteworthy that pyritic and silicic-altered rocks having anomalous gold values continue at depth at Hickey's Pond. Dimmell *et al.* (1992) describe a 45° drillhole (320° azimuth), collared in the main silica zone, that intersects a major zone of grey, pyritic silica and silica–sericite alteration, that returned anomalous gold values (from 0.1 to 0.6 g/t) along most of its 75.6 m length (Corona Corporation hole 90-03). The zone contains very local disseminations of bornite, having corresponding gold values up to 1 g/t Au over 1 m. Resampling of the hole confirms the gold anomaly and has identified subzones of fragmental texture defined by buff-to-beige silica-altered clasts in a grey pyriterich (15 to 20 percent) massive silicic matrix. Small pyrite-free pods of silicic-altered material within these zones contain up to 97 percent silica.

Table 1. Representative lithogeochemistry of the hydrothermal alteration zones mapped at surface at the Hickey's Pond prospect (grab samples)

Field	Alteration facies and description	SiO ₂	Al ₂ O ₃	TiO ₂	Fe2O3 Total %	MnO %	MgO %	CaO %	Na2O	K ₂ O
	Theration factes and description	70	70	70	10101 70	70	70	70	70	/0
	Unit A									
OB-97-256	vuggy silica	97.68	0.08	0.46	0.82	0.00	0.00	0.01	0.03	0.00
OB-97-257	vuggy silica	95.10	0.90	0.44	0.78	0.00	0.00	0.03	0.09	0.11
OB-98-11	vuggy silica	80.50	6.76	0.44	0.97	0.00	0.00	0.00	0.80	0.60
OB-98-12	vuggy silica	89.19	2.21	0.84	3.12	0.00	0.00	0.00	0.19	0.24
OB-97-258	sulphide-rich silicic zone	74.78	1.44	0.29	6.25	0.00	0.00	0.04	0.23	0.08
OB-98-3	massive silica, no vugs	96.80	0.27	0.51	0.38	0.00	0.00	0.00	0.00	0.00
OB-98-13	vuggy silica	92.20	2.39	0.41	0.79	0.00	0.00	0.00	0.14	0.34
OB-98-43	calcedonic silica	96.23	0.89	0.30	1.16	0.00	0.00	0.00	0.00	0.12
	Unit B1 and B2									
OB-97-254	quartz-alunite-pyrite	56.25	12.46	0.65	7.81	0.00	0.00	0.14	1.35	1.62
OB-98-15	massive silicic + pyrite	91.68	1.28	0.33	3.36	0.00	0.00	0.00	0.03	0.23
OB-98-16	quartz-alunite-pyrite	53.24	11.71	0.72	11.33	0.00	0.00	0.00	1.43	1.31
OB-97-255	quartz-alunite-pyrite	64.47	11.45	0.52	3.17	0.00	0.00	0.07	1.28	1.53
OB-97-264	quartz-alunite-pyrite	69.56	8.70	0.54	4.24	0.00	0.00	0.06	0.98	1.18
OB-98-35	quartz-alunite-pyrite	72.44	9.34	0.50	1.83	0.00	0.00	0.00	0.99	1.11
	Unit C									
OB-98-28	vuggy silica + hematite	75.97	9.47	0.58	7.21	0.00	0.00	0.04	0.29	2.16
OB-98-32	quartz-alunite-pyrite	62.21	11.92	0.56	3.63	0.00	0.00	0.05	1.83	0.67
OB-98-34	vuggy pyrite	68.02	10.29	0.61	2.59	0.00	0.00	0.00	1.16	1.15
OB-97-261	quartz-hematite schist	70.39	8.05	0.64	7.10	0.00	0.00	0.08	0.90	1.04
	Unit E									
OB-98-19	quartz-alunite-lazulite schist	65.46	13.01	0.51	0.08	0.00	0.00	0.05	0.75	2.53
OB-98-23	quartz-alunite-lazulite schist	64.18	13.49	0.52	0.02	0.00	0.00	0.02	1.45	1.74
OB-97-263	quartz-alunite-lazulite schist	57.62	16.00	0.53	0.11	0.00	0.00	0.14	1.29	2.76
	Unit F									
OB-98-17	quartz-sericite schist	72.29	13.47	0.24	1.66	0.09	0.40	1.47	3.19	3.54
	Unit G barren									
OB-98-25	hematite-rich breccia	58.32	7.77	0.47	20.68	0.00	0.00	0.08	0.99	0.52
OB-98-26	hematite-rich breccia	67.15	8.17	0.60	11.36	0.00	0.00	0.11	0.85	0.85
OB-98-27	hematite-rich breccia	77.78	0.66	0.57	20.13	0.00	0.00	0.00	0.02	0.03
	Unit G mineralized									
OB-98-36	hematite-rich breccia	72.64	4.93	0.35	15.23	0.00	0.00	0.05	0.45	0.57
OB-98-38	deformed hematite breccia	75.23	8.45	0.37	2.28	0.00	0.00	0.00	0.99	0.85
OB-98-39	hematite-rich breccia	76.42	7.84	0.36	2.82	0.00	0.00	0.02	0.76	0.98
OB-98-40	hematite-rich breccia	88.36	1.35	0.44	8.82	0.00	0.00	0.00	0.12	0.07
OB-97-262	hematite-rich breccia	74.46	4.22	0.27	14.68	0.00	0.00	0.11	0.51	0.39

NOTE: The high LOI reflects high SO₄ concentration in alunite-rich ((Na,K)Al₃(SO₄)₂OH₆) alteration.

eld	P_2O_5	L.O.I.	Total	Au	Ag	Sb	As	Cu	Pb	Zn	Mo	Zr	Ba
umber	%	%	%	ррь	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.07.054	0.00	0.27	00.44	12250	15.0	0.2	21	26	0				50
B-97-256	0.00	0.37	99.44	13350	15.3	92	31	26	0	4			<50
B-97-257	0.06	0.84	98.38	5179	<5	31	16	41	0	0	•	• • •	91
B-98-11	0.11	9.03	99.20	15400	46	1040	1120	119	353	3	2	201	483
B-98-12	0.03	3.85	99.64	5850	40	2870	2840	439	117	7	0	201	117
B-97-258	0.00	9.74	98.21	7594	109	8323	15110	34125	0	572			<50
B-98-3	0.00	0.52	98.43	1130	<5	20	10	19	12	0	0	201	19
B-98-13	0.05	1.93	98.23	5120	6	71	29	24	114	2	0	201	194
B-98-43	0.00	0.80	99.47	627	5	40	26	13	17	1	0	201	44
B-97-254	0.18	19.60	100.19	2356	<5	26	15	61	0	13			277
B-98-15	0.02	2.43	99.33	554	5	26	8	50	48	3	0	201	59
B-98-16	0.09	20.13	99.94	346	5	20	17	48	234	140	2	201	483
B-97-255	0.16	16.32	99.12	<4	<5	16	38	34	0	22			405
B-97-264	0.09	12.98	98.43	<4	<5	12	22	81	0	5			334
B-98-35	0.11	12.61	98.92	212	<5	20	22	103	141	0	3	201	514
	0.10	2.25	00.22	1260		10	10	10	120	7	4	201	400
B-98-28	0.19	3.35	99.23	1360	<)	19	19	12	129	/	4	201	429
B-98-32	0.21	17.53	98.59	190	<>	16	8	4	16/	4	2	201	682
B-98-34	0.11	14.84	98.74	650	2	29	32	27	1/4	4	0	201	506
B-97-261	0.14	10.66	99.11	<4	<>	33	16	22	0	17			626
B-98-19	0.27	15.90	98.56	170	2	18	4	1	306	3	2	201	816
B-98-23	0.14	16.59	98.16	160	3	17	4	1	59	3	2	201	653
B-97-263	0.38	20.82	99.94	<4	<5	19	4	13	0	0			880
B-98-17	0.04	2.25	98.65	24	<5	18	23	4	11	51	0	0	899
B-98-25	0.27	10.05	99.14	45	<5	20	13	3	128	9	0	201	825
B-98-26	0.31	10.18	99.56	180	5	30	21	4	82	7	2	201	1000
B-98-27	0.04	0.92	100.13	170	<5	22	32	5	16	12	0	201	56
B-98-36	0 19	5 83	100.23	5000	7	27	17	4	375	9	0	0	451
B-98-38	0.10	10.88	99.13	249	<5	31	5	2	264	3	õ	0	483
B-98-39	0.17	9.52	98 88	5000	<5	32	7	- 1	484	3	õ	0	625
B-98-40	0.04	1.76	100.93	4630	5	40	, 14	3	85	5	õ	0	139
B-97-262	0.18	5.62	100.56	3624	9.1	29	27	37	0	17	Ŭ	5	17
B-98-36 B-98-38 B-98-39 B-98-40 B-97-262	0.19 0.10 0.17 0.04 0.18	5.83 10.88 9.52 1.76 5.62	100.23 99.13 98.88 100.93 100.56	5000 249 5000 4630 3624	7 <5 <5 5 9.1	27 31 32 40 29	17 5 7 14 27	4 2 1 3 37	375 264 484 85 0	9 3 3 5 17	0 0 0 0		0 0 0

 Table 1. (Continued)



Plate 5. Small-scale F₂ fold of hematite–alunite–quartz banding from Unit C, Hickey's Pond prospect.

STEWART PROSPECT

The Stewart prospect (Dimmell and MacGillivray, 1993) is a locally auriferous, composite zone of pyrite-rich aluminous and silicic alteration within the Eastern Belt of the Hickey's Pond-Point Rosie alteration system (Figure 2). The prospect, discovered by Kennecott Corporation in 1985, is located near Powderhorn Lake at the knee of the Burin Peninsula. Alteration occurs within penetratively deformed, felsic volcanic rocks of the Marystown Group, peripheral to the southeastern margin of a large composite pluton of highlevel hornblende-biotite granite, felsite and quartz porphyry (O'Brien and Taylor, 1983). The prospect was optioned to Novamin Resources in 1986, who mapped and sampled it, and carried out geophysical surveys and a 4-hole diamonddrilling program (see Wright, 1986a,b; Dimmell and MacGillivray, 1990a,b). Corona Corporation subsequently optioned the property in 1988, and carried out geochemical surveys and follow-up trenching and channel sampling. Resulting anomalies were tested by 3 diamond-drill holes that were collared in the southwestern part of the alteration zone. Although none of the drillholes encountered economic mineralization, anomalous gold (0.25 g/t over 63 m, 0.84 g/t over 5 m and 2.9 g/t over 1 m), associated with chalcopyrite, azurite, cuprite and molybdenite, was encountered in alunite-pyrophyllite-bearing rocks (Dimmell and MacGillivray, 1993). A detailed description of the property geology and exploration results is given in Dimmell and MacGillivray (1993). The property is currently held as an extended license by Ralph Stewart, the original discoverer of the prospect.

HYDROTHERMAL ALTERATION

Hydrothermal alteration and anomalous gold are hosted primarily by quartz-phyric felsic tuff and quartz-feldspar porphyry. Altered rocks occur in a 4-km-long and 400- to 700-m-wide zone, bounded to the northwest and west by mainly unaltered, medium- and coarse-grained hornblende-biotite granite, and to the southeast by epidote-chlorite-altered basalt and mafic breccia. The eastern limit of the alteration at surface is not clearly established, and variably pyritic and silicic-altered rocks of similar felsic volcanic protolith are exposed sporadically for several kilometres farther east, between Powderhorn Lake and the Burin Peninsula Highway.

The extensive glacial deposits and felsenmeer that cover the zone hamper the establishment of an internal subdivision of alteration facies that can be readily mapped on a prospect scale. Hence our understanding of the internal structure of the zone remains unclear at this time, and further detailed study is needed to establish the geometry of alteration. However, regional observations coupled with those from the poorly exposed trenches at the south end of the zone, and from core drilled in the same area, clearly indicate that the Stewart prospect represents part of a larger, well-developed, advanced argillic alteration zone, typical of a high-sulphidation epithermal system. On a regional scale, progressively deeper levels of the system are encountered toward the north and west.

Variably intense silicic and pyritic alteration is characteristic of much of the alteration zone, and is associated with the development of pyrophyllite, sericite, specular hematite and rutile. Fluorite is also present, mainly as a fracture-coating; traces of molybdenite, azurite, cuprite and chalcopyrite have been described in drill core (Dimmell and MacGillivray, 1993). Fine-grained disseminated pyrite is widespread at surface and in drill core, but is highly variable (3 to 20 percent) in its concentration. The locally developed pink hue of the altered rocks is consistent with the presence of alunite, which has also been reported by Dimmell and MacGillivray (1993). The grey quartz-pyrophyllitesericite-pyrite schists contain massive silicic pods and lenses, having up to 97.9 percent SiO2; they occur both in outcrop and drill core. Other than the local presence of relict grey quartz crystals, these silica pods are essentially featureless. Both the silica-rich and the sericite-pyrophyllitebearing rocks contain disseminated specular hematite. Quartz-pyrophyllite-hematite schist is locally exposed and is markedly similar to alteration Unit C at the Hickey's Pond prospect (see above).

A large area of beige to light-grey advanced argillic alteration is exposed at the northeastern end of the Stewart prospect. These siliceous-looking rocks are featureless and devoid of sulphides, but contain centimetre- to metre-scale pods composed of quartz–pyrite schist (3 to 5 % pyrite), containing possible alunite. These rocks gradually pass south–southwest into high-strain quartz–pyrophyllite– sericite–schist containing localized pyrite.

The overall degree of strain superimposed on the altered rocks is medium to high. Local structural relationships indicate that the hydrothermal alteration is affected by a penetrative S_1 fabric, suggesting that – on structural grounds alone – alteration is most probably pre- to early-D₁. This S_1 fabric is itself folded by small-scale F₂ folds of pyrophyllite–sericite-rich alteration, which are well displayed in drill core.

DISTRIBUTION OF GOLD

Available data demonstrate that, within the advanced argillic alteration zone, the concentration of gold tends to show a positive correlation with the overall pyrite abundance, as indicated by Fe_2O_3 content, and an inverse relationship to the amount of pyrophyllite and sericite. Core logging indicates that the 1.2 g/t and 2.95 g/t Au intersections (each over 1 m) reported by Corona Corporation from drillhole 90-02 are associated with highly silicic alteration, containing 5 to 10 percent pyrite and traces to 1 percent of a blue mineral, tentatively interpreted as bornite.

Most of Corona Corporation's drillhole 90-02 returned gold values between 0.1 to 0.3 g/t from within silicic, pyriterich advanced argillic alteration (see Dimmell and MacGillivray, 1993). This section through the alteration zone shares strong analogies with the quartz-sericite-pyrophyllite-pyrite schists present in the structural footwall and hanging wall at the Hope Brook Mine (Dubé et al., 1998). The best gold-bearing intersections in this hole are associated with a disseminated copper-bearing mineral (bornite?), a relationship that is predictable, given the high-sulphidation nature of the system (e.g., Arribas, 1995). A similar correlation of anomalous copper (up to 0.23 %) with anomalous gold (0.3 to 0.4 g/t) is evident in Novamin drill core (e.g., drillhole NG-1, 700 m northeast of Corona drillhole 90-02; Dimmell and MacGillivray, 1993). Although the silicic alteration is locally intense, there is no well-developed zone of massive silicic alteration, and vuggy silica is absent. As is the case with the Hickey's Pond prospect, the absence - at surface - of such alteration is consistent with the lack of a significant mineralized zone. However, the consistently anomalous (0.1 to 0.3 g/t) gold concentration found over wide intersections of altered rock, coupled with the local presence of higher gold values (≤ 2.95 g/t), indicates that there is potential for a gold-bearing massive silicic and vuggy ore zone within the hydrothermal system. Consequently, the presently defined alteration zone remains untested, especially at depth. Further surface exploration is also warranted along strike to the east of the Stewart prospect, and in the area northeast of Powderhorn Lake, where quartz–porphyry sills and lenticular quartz–feldspar porphyritic intrusions have been emplaced into the same volcanic package.

KELSTONE PROPERTY

The Kelstone property at Marystown represents one of the single largest volcanic-hosted auriferous alteration zones exposed on the Burin Peninsula. Hydrothermal alteration, with variously anomalous concentrations of gold, copper, silver, and zinc (Table 2), is hosted by Marystown Group volcanic rocks of mainly felsic composition. Alteration in the main prospect is exposed over a continuous area of at least 0.5 km² near the old Marystown landfill. A visually impressive aspect of this alteration zone is the presence of subzones of quartz-sericite-pyrite alteration that contain up to 15 to 20 percent fine- and coarse-grained pyrite (1 to 3 mm), locally anomalous in gold (0.2 g/t; Table 2; Plate 6). Gold occurs in dark, locally specular hematite-bearing volcanic rocks and bleached silicic-altered pyrite-bearing rocks, locally affected by late hematite remobilization. Mineralized bedrock having up to 5 percent coarse-grained pyrite yields assays up to 2.2 g/t Au; angular subcrop has returned assays up to 5 g/t Au, 17 g/t Ag, 0.4 % Cu and 0.04 % As (A. Stone and D. Kelly, personal communication, 1998). Elsewhere on the property, anomalous copper (0.3 %) and zinc (.07 %) is associated with felsic hydrothermal breccia and phyllic-altered rhyolitic to intermediate tuffs. Anomalous concentrations of lead (0.7 %) and zinc (.07 %) are locally developed in soils adjacent to areas of sulphide-bearing rhyolite north of the main area of gold mineralization and alteration.

Recently completed diamond drilling demonstrates that moderate to strong phyllic and silicic alteration continue at depth, and are associated with disseminated bornite, chalcopyrite, and pyrite (First Labrador Acquisitions Inc., press release, January 15, 1999); no gold assays were reported. Auriferous alteration (4 g/t Au in grab samples) also occurs 3 km north–northwest of the Kelstone property, along a linear that intersects the mineralization at Kelstone (Braxton-Bradley showing; First Labrador Acquisitions Inc., ibid.). Gold is reported to occur in grey silicic rocks and in enveloping zones of phyllic alteration. Angular cobbles in the same area are composed primarily of hydrothermal breccia, and multistage buff and grey silica containing folded quartz-rich veins. This float contains chalcopyrite, bornite, galena and pyrite, and has returned assays up to 2.4 g/t Au, 108 g/t Ag, 1.68 % Cu, 1.89 % Zn and 0.31 % Pb (First Labrador Acquisitions Inc., press release, February 8, 1999).

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Field Number	Alteration facies and description	SiO2 %	Al2O3 %	TiO2 %	Fe2O3 Total %	MnO %	MgO %	CaO %	Na2O %	K2O %
OB-98-142	sericitized felsic volcanic rock: disseminated pyrite	72.89	11.35	0.02	5.69	0.03	0.08	0.00	0.02	3.74
OB-98-143	silicified, sericitized and strongly pyritized volcanic rock	56.18	9.78	0.05	19.74	0.02	0.18	0.00	0.00	3.23
OB-98-146	felsic breccia with malachite, bornite and covellite	74.91	13.14	0.02	2.56	0.04	0.21	0.00	0.06	6.74
OB-98-151	quartz-sericite-pyrite alteration (low strain)	69.17	11.66	0.01	9.23	0.00	0.12	0.00	0.02	3.68
OB-98-153	quartz-sericite-pyrite alteration	75.60	11.59	0.01	6.10	0.00	0.08	0.00	0.00	3.60
OB-98-154	semimassive pyrite in quartz– sericite–pyrite alteration	65.24	10.83	0.01	13.32	0.02	0.10	0.00	0.00	3.28
OB-98-155	sericite-pyrite alteration in felsic volcanic rock	76.14	12.00	0.01	5.92	0.01	0.09	0.00	0.01	3.64
OB-98-156	chloritic volcanic rock: malachite, pyrophyllite	72.58	12.99	0.01	8.19	0.15	0.23	0.00	0.01	3.10
OB-98-157	sericite-pyrite alteration (5 to 7% pyrite)	71.00	12.04	0.02	7.76	0.03	0.07	0.00	0.00	3.65
OB-98-158	mafic volcanic rock with coarse-grained pyrite	48.26	8.41	0.01	26.40	0.06	0.15	0.00	0.00	2.29

Table 2. Representative lithogeochemistry of hydrothermally altered rocks from part of the Kelstone property (grab samples)



Plate 6. Aggregates of coarse-grained pyrite in sericite silica pyrite alteration, Kelstone property.

Parts of the Kelstone alteration system are analogous to the Stewart prospect and the Hope Brook Mine (e.g., the presence of an extensive quartz–sericite–pyrite alteration zone). Similarities exist with the Hickey's Pond prospect, including the local presence of specular hematite-bearing altered rocks. The Au–As–Cu signature of the alteration (Table 2) is comparable to that at Hickey's Pond, and is consistent with high-sulphidation epithermal-style alteration. The low to medium strain at the Kelstone property, the high copper contents, and the possibility of intrusive rocks at depth are all positive features of this prospect. Its discovery indicates the presence of a new, under-explored epithermal alteration belt on the southern Burin Peninsula.

Table 2. (Continued)													
Field Number	P2O5 %	L.O.I. %	Total %	Au ppb	Ag ppm	Sb ppm	As ppm	Cu ppm	Pb ppm	Zn ppm	Mo ppm	Zr ppm	Ba ppm
OB-98-142	0.00	4.84	98.63	0	0	57.7	6850	177	35	71	7	82	229
OB-98-143	0.00	11.04	100.18	0	0	28.4	5980	96	46	46	0	104	196
OB-98-146	0.00	1.61	99.28	0	11	2.0	266	3521	0	294	1	91	1995
OB-98-151	0.00	5.93	99.80	74	0	4.9	805	31	23	21	0	85	135
OB-98-153	0.00	3.30	100.24	59	0	8.1	439	107	125	133	2	66	157
OB-98-154	0.00	7.43	100.20	226	5	21.1	1420	106	791	62	2	79	158
OB-98-155	0.00	2.96	100.76	2660	0	1.7	178	76	12	22	2	84	102
OB-98-156	0.00	2.61	99.85	957	15	10.9	37	2020	32	138	8	102	79
OB-98-157	0.00	5.14	99.67	1600	0	1.8	253	151	8	21	2	91	83
OB-98-158	0.00	14.04	99.58	1160	0	22.9	1090	917	114	53	0	72	62

A NOTE ON SOME OTHER PROSPECTS

The Monkstown Road lazulite showing (Huard, 1990; Huard and O'Driscoll, 1986) and the nearby occurrences of specularite schist and silica alteration at Little Pond and Paradise River, together display a number of strong analogies with the Hickey's Pond prospect. Most notable is the presence of massive silica alteration, in which SiO2 values range between 90 and 96 percent. Foliated hematite-silica breccias similar to those at Hickey's Pond are locally exposed, although they are apparently not anomalous in gold. Late-stage, specularite-(+lazulite)-bearing deformed quartz veins similar to those at Hickey's Pond are well developed. As is the case at Hickey's Pond, these veins contain coarse-grained aggregates of remobilized phases from within the advanced argillic zone. Zones of sericite-silica-pyrite alteration are well developed adjacent to the silica alteration, and are the focus of high-strain zones, with reverse sense of motion (Plate 7). Despite the apparent



Plate 7. Shear bands displaying reverse sense of motion, developed in quartz-sericite-pyrite alteration, Monkstown Road showing.

absence of gold mineralization in outcrop at the Monkstown Road showing and nearby alteration zones (Figure 3), this prospect clearly demonstrates that the area remains an important exploration target.

The Point Rosie prospect comprises extensive zones of siliceous advanced argillic alteration and locally developed areas of grey silicic alteration containing disseminated pyrite. Local zones of highly silicic breccia, containing up to 3 to 5 percent disseminated pyrite, represent interesting exploration targets. The Point Rosie prospect presents evidence of a large-scale, alteration zone (or zones), although there are very limited sulphides (mainly pyrite) in the small portion of the hydrothermal system studied. The larger alteration zone is several kilometres long, and lies more than 70 km southwest of the alteration at Monkstown Road. The prospect clearly illustrates the vast scale of the epithermal alteration system in this part of the Burin Peninsula.

Extensive zones of silica-sericite-pyrite alteration are exposed in a semi-continuous belt in and around the Bay de l'Eau River area, extending southward to Brookside. Alteration is spatially associated, in part, with several smaller plutons related to the Cape Roger Mountain Granite (O'Brien et al., 1984). Zones of massive silica are locally exposed in the same area, and farther west, on-strike (regionally) with the Stewart prospect. Heavily disseminated to semimassive pyrite is developed in several locations, and is locally anomalous in gold (A. Turpin, personal communication, 1998). Similarly, zones of silica-sericite-pyrite alteration occur south of Brookside, in a continuous northeast-trending belt extending to the Baine Harbour area and thence south toward Red Harbour. Much of the alteration is marginal to, or within, a regionally extensive, sill-like body of quartz-feldspar porphyry (O'Brien and Taylor, 1983).

Aluminous alteration hosted by Marystown Group volcanic rocks also occurs in the poorly exposed region north of the (Devonian) St. Lawrence Granite, near Stroud's Pond, approximately 25 km southwest of the Kelstone property (Van Alstine, 1948; Strong et al., 1978b). A dumortieritebearing, aluminosilicate-rich zone of hydrothermal alteration is developed in massive and devitrified spherulitic rhyolite flows and lithophysae-bearing ash-flow tuffs. Silica-pyrophyllite-sericite-bearing altered rocks locally contain dumortierite and, more rarely, andalusite, as grains and irregular patches; dumortierite also occurs in veinlets up to 2.5 cm thick (Van Alstine, 1948). Although no gold values have been reported from the few surface exposures at the property, the presence of these phases, particularly dumortierite, represents an important mineralogical anomaly (cf., Ririe, 1990; Taner and Martin, 1993) that is the expression of acid alteration commonly associated with precious-metal deposition in high-sulphidation and porphyry Cu-Au systems.

DISCUSSION

The ability to identify the style of precious-metal-bearing hydrothermal alteration is a powerful geological tool that permits the correct use of the known geometry of an alteration system to predict where auriferous rocks might be encountered within it. Although differing styles of epithermal alteration share some similar alteration facies (e.g., silica alteration in both low- and high-sulphidation systems), the relative position of these facies to ore-bearing cores of the systems vary (e.g., White and Hedenquist, 1995). Within any particular alteration style, gold ore has a strong and often unique affinity with particular facies and textures. In the case of high-sulphidation gold deposits, gold ore is typically associated with vuggy silica (Arribas, 1995 and references therein).

The use of alteration facies as a "navigational aid" within regional belts of epithermal alteration on the scale of those encountered on the Burin Peninsula is critical for exploration success. Most of the known epithermal systems on the Burin Peninsula display some or all of the characteristics of high-sulphidation, epithermal-style alteration systems. The surface exposures of these zones are mainly within well-developed and extensive subzones of advanced argillic alteration, which in most high-sulphidation gold deposits, occur peripheral to the ore-bearing, vuggy core of the system. That many of the Burin Peninsula advanced argillic zones are anomalous in gold and arsenic, and are associated with local zones of massive silica, indicate that the host alteration systems have potential for containing vuggy silica cores having economic gold concentrations. The presence of gold concentrations in the range of 0.2 to 1.0 g/t, considering the nature of the pyritic advanced argillic alteration at Hickey's Pond and Stewart prospects, for example, is predictable and positive, indicating that the larger alteration envelope is auriferous. The strong association of gold and vuggy silica alteration in most high-sulphidation systems on a global scale is also the case on the Burin Peninsula, and is clearly corroborated by the data from Hickey's Pond.

Establishing the distribution of alteration facies to restore the original geometry of the Burin Peninsula alteration zones is further complicated by the intensity of strain superimposed on most of these systems. Chronological relationships indicate that the alteration systems were formed prior to the main stage of strong ductile deformation that has affected most of the altered rocks. Alteration systems on the southern Burin Peninsula record relatively lower superimposed strain, and thus may be better preserved. Structural repetition and thickening of alteration and the potential for local remobilization and enrichment of metals may be a positive aspect of the northern Burin Peninsula alteration systems. A number of striking analogies exist between the Burin Peninsula alteration zones and the coeval Hope Brook gold deposit (McKenzie, 1986; Yule *et al.*, 1990; Stewart, 1992; Dubé *et al.*, 1998). Not only are they alike in terms of their tectonic setting, and the nature and age of their host rocks, but also in terms of the nature and mineralogy of the hydrothermal alteration, the style and setting of mineralization, and the degree and nature of superimposed structural complexities. Two key elements of the Hope Brook deposits pertinent to gold exploration on the Burin Peninsula are highlighted here. The first is the relative distribution of hydrothermal alteration facies; the second is the relationship of alteration to intrusions, particularly quartz–feldspar porphyries.

The hydrothermal alteration system at Hope Brook is characterized by: 1) advanced argillic alteration containing pyrophyllite, andalusite, kaolinite, alunite, sericite, quartz, pyrite and rutile, and 2) two main stages of massive silicic alteration. Initial silica alteration is buff in colour, barren to weakly auriferous, massive and regionally extensive. The more restricted, second stage of silicic alteration is host to the gold ore. This grey silica alteration has a vuggy texture and is characterized by several percent pyrite and lesser amounts of chalcopyrite and bornite (Dubé et al., 1998). The advanced argillic and silicic alteration is spatially and genetically related to a quartz-feldspar porphyry sillndyke complex located in the structural hanging wall of the ore zone (McKenzie, 1986; Yule et al., 1990; Stewart, 1992; Dubé et al., 1998). This intrusive complex is associated with the multiphase Roti Intrusive Suite (B. O'Brien et al., 1991), which is comparable in terms of age, texture and composition with the Swift Current Granite and related plutons of the northern and central Burin Peninsula.

The data from Hope Brook clearly demonstrates that a priority exploration strategy applicable to the analogous, but much larger alteration systems of the Burin Peninsula is the location of massive silicic alteration within the zones of auriferous advanced argillic alteration exposed at most of the known prospects. Definition of alteration vectors (cf., Corbett and Leach, 1998) may lead to discovery of vuggy massive silicic alteration zones, like those at Hope Brook. The presence of vuggy-silica-hosted, high-grade mineralized rocks at the Hickey's Pond prospect, coupled with the anomalous gold values within the advanced argillic alteration zone(s), there and at the Stewart prospect, indicates that these systems are auriferous, and potentially cored by massive silicic ore zone(s). The strong spatial association between epithermal alteration and intrusions in both the Hope Brook area and the Burin Peninsula is striking. Porphyry phases of these intrusions, such as those described by Hussey (1978) and O'Brien and Taylor (1983), may represent potential exploration targets, for both epithermal- and porphyry-related Cu-Au systems.

The Neoproterozoic record of the Burin Peninsula and adjacent regions includes two major events that, together, point to a genuine but little-recognized potential for goldrich volcanogenic massive sulphide (VMS) mineralization. These include the formation of subaerial volcano-plutonic arcs (e.g., Marystown Group) and coeval to slightly younger marine to terrestrial sedimentary basins (e.g., upper Musgravetown Group and related rocks; Grandy's Pond arenite belt; see Figure 1), and the formation of large-scale advanced argillic alteration systems (see above). Gold-rich VMS deposits are currently interpreted as the shallow-water equivalent to subaerial, high-sulphidation epithermal mineralization (e.g., Sillitoe et al., 1996). They are mostly hosted by felsic volcanic tuffaceous rocks, near the interface with basaltic flows or sedimentary rocks, and commonly occur in shallow-water sequences that show a transition to subaerial conditions (e.g., Poulsen and Hannington, 1996). Both the Marystown Group and the adjacent Musgravetown Group (e.g., O'Driscoll and Muggeridge, 1979; O'Brien and Taylor, 1983) contain such stratigraphic transitions recorded in similar facies, and should thus be considered as regional exploration targets for such Au-rich VMS deposits, particularly in light of the widespread Neoproterozoic high-sulphidation alteration in the former. The presence of Au-Ag-As-Pb-Zn mineralization associated with semimassive to massive pyrite on Merasheen Island (O'Driscoll and Muggeridge, 1979; P. Crocker, written communication, 1998) may be one example of such a mineralizing system.

SUMMARY

- The late Neoproterozoic epithermal alteration zones exposed on the Burin Peninsula display many characteristics of high-sulphidation gold-bearing systems. The alteration and gold mineralization is interpreted to form by processes directly related to leaching and subsequent metal deposition by magmatically derived, low-pH fluids. Such fluids typically form from the mixing of magmatic volatiles with meteoric waters (e.g., Heald *et al.*, 1987; Hedenquist, 1987).
- The ca. 100-km-long Hickey's Pond–Point Rosie alteration system represents one of the largest metamorphosed high-sulphidation epithermal systems known in Canada. The anomalous gold content of the advanced argillic zones within the system, coupled with the local occurrence of high-grade gold in vuggy silica, is strong indication of potential economic mineralization. The striking analogy with the Avalonian Hope Brook gold deposit, in terms of age and alteration style, further demonstrates this potential.
- The Hickey's Pond–Point Rosie alteration system contains at least two separate belts of alteration, each hav-

ing slightly different stratigraphic settings. Both are hosted by volcanic rocks of the 590 to 565 Ma Marystown Group. The western alteration belt contains the Monkstown Road, Ridge, Strange, Little Pond, Paradise River and Bullwinkle showings and includes the Point Rosie prospect (Huard and O'Driscoll, 1986; O'Brien *et al.*, 1998). Many of these alteration zones are located close to the boundary between felsic volcanic rocks and volcanogenic, shallow-marine to terrestrial sediments of the regionally extensive Grandy's Pond arenite belt (*see* Figures 1 and 2). This setting is analogous with late Neoproterozoic high-sulphidation-type and related gold deposits in coeval rocks in the Avalonian Carolina Slate Belt (*see* O'Brien *et al.*, 1998 and references therein).

- The eastern alteration belt includes the Hickey's Pond prospect and the Chimney Falls and Tower showings, as well as the Stewart prospect and other newly recognized zones between there and the Bay de l'Eau River area. Alteration is proximal to the eastern or southeastern boundary of the Swift Current Granite and plutons of the Cape Roger Mountain and Burin Knee granites. Most of the significant gold mineralization discovered to date on the north–central Burin Peninsula is associated with this regionally extensive boundary. The association of alteration with porphyritic intrusions is an important spatial and, most probably, genetic element of this part of the Hickey's Pond–Point Rosie system, which is shared by many similar epithermal preciousmetal ore systems.
- The geological boundaries associated with both alteration belts continue north of the Burin Peninsula, and have been mapped northward to Bonavista Bay. These are highly prospective, metallogenically significant boundaries that warrant systematic exploration.
- Most of the known alteration zones on the Burin Peninsula represent the pyritic advanced argillic facies of larger or potentially larger epithermal alteration systems. In typical high-sulphidation systems, advanced argillic alteration with anomalous gold (with or without copper, arsenic and antimony) is developed adjacent to a vuggy silica core, which typically represents the principal host rock of the gold ore in such systems. Thus, the occurrence of anomalous gold values within the advanced argillic zones is an important and positive exploration result, which is consistent with the potential presence of an auriferous core to the larger system.
- Massive silica alteration is best developed at the Hickey's Pond and Monkstown Road prospects. There is a strong correlation between gold and the presence of vuggy silica within the massive silica zone at Hickey's

Pond, that is predictable, given the nature of the alteration. The presence of gold-bearing vuggy silica with advanced argillic alteration at surface, coupled with the presence of extensive advanced argillic alteration at depth argues for high, largely untested potential (at depth) for gold mineralization. The potential for vuggy silica material at depth within or proximal to the geologically similar Monkstown Road prospect should be considered high.

- The advanced argillic zones at both the Stewart prospect and Kelstone property are anomalous in gold. Gold values have a positive correlation with silica alteration and copper values at the Stewart property.
- The precious- and base-metal signatures of the alteration zones at the Kelstone property and the Hickey's Pond prospect display several marked similarities. The relatively low strain encountered at Kelstone is a positive factor, *vis-a-vis* exploration.
- The Stroud's Pond alteration zone represents an important mineralogical anomaly, indicative of acid alteration and, potentially, gold deposition.
- Significant parts of the alteration encountered in drillholes from the Hickey's Pond (Corona 90-03) and Stewart (Corona 90-02) prospects are similar in many respects to elements of the Neoproterozoic alteration system that lies adjacent to gold ore at the Hope Brook Mine (Dubé *et al.*, 1998). The latter is hosted by Avalonian rocks that are exactly coeval with and lithologically similar to those in the Hickey's Pond–Point Rosie belt. The presence in subsurface of alteration having constantly anomalous gold values suggests a potential for discovery of ore at depth in both prospects.
- The analogy between the Burin Peninsula alteration systems and those at the Hope Brook gold deposit is striking. Alteration zonation defined at Hope Brook can be employed to navigate within the large-scale hydrothermal system(s) on the Burin Peninsula and to define alteration vectors that may lead toward potentially vuggy massive silicic ore zone(s). The vuggy high-grade mineralized zones present at the Hickey's Pond prospect is clear evidence that such a style of alteration and mineralization does exist on the Burin Peninsula.
- The Swift Current Granite (Burin Peninsula) is analogous to the Roti Intrusive Suite (Hope Brook area) in terms of age, texture, composition and relationship to gold mineralization in coeval stratified rocks. Mineralization and alteration at the Hope Brook deposit is related, both spatially and genetically, to a quartz

feldspar porphyry sill dyke complex of the Roti Intrusive Suite. The Swift Current Granite, its marginal quartz feldspar porphyry bodies (e.g., Hussey, 1978) and its surrounding host rocks, represent important exploration targets for both epithermal- and porphyryrelated Cu–Au systems. A similar case can be made for related intrusions along strike, such as the Cape Roger Mountain and the Burin Knee granites. The large number of smaller stocks, plugs and sheets exposed in the region between these larger granitic complexes represents equally, if not more prospective terrane, with more extensively preserved pluton roof zones.

ACKNOWLEDGMENTS

The authors wish to acknowledge the cheerful and able assistance provided by Jeff Meade. We also acknowledge the aid of the following individuals: Peter Dimmell, Chris Finch, Nathaniel Noel (First Labrador Acquisition Inc.), Ralph Stewart and Alex Turpin. Paul Crocker, Dan Kelly and Albert Stone provided the authors with unpublished geochemical data. Major- and trace-element data were provided by the Geological Survey of Newfoundland and Labrador, INRS-Quebec Geoscience Centre and Becquerel Labs; Roger Mason (Department of Earth Sciences, Memorial University) provided X-ray diffraction data. The figures and plates were prepared with the assistance of Dave Leonard and Tony Paltanavage (GSNL) and Luce Dubé (INRS-Quebec Geoscience Centre). Our work in the Hickey's Pond-Point Rosie alteration system would not have been possible without the important geological groundwork carried out by Alan Huard.

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Note: Geological Survey file numbers are included in square brackets.