Metallogeny of the Avalonian Mira Terrane, Southeastern Cape Breton Island, Nova Scotia: a Preliminary Study

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Introduction

The Mira terrane of Cape Breton Island is composed of northeast-trending belts of Neoproterozoic volcanic, sedimentary and plutonic rocks separated by regional-scale faults and/or Cambrian and Carboniferous sedimentary sequences (Fig. 1). Also present in the terrane are scattered Devonian (ca. 370–360 Ma) granitoid plutons and associated skarns.

The Neoproterozoic rocks include three magmatic associations (Barr et al., 1996; Willner et al., 2015) with ages of ca. 680 Ma (Stirling Group), ca. 620 Ma (Coxheath, East Bay Hills, and Pringle Mountain groups and related plutons), and ca. 575–560 Ma (Fourchu and Main-à-Dieu groups and related plutons). Known mineral occurrences in these rocks were described by Macdonald (1989). However, the metallogenetic potential of the Mira terrane has not been subsequently assessed in

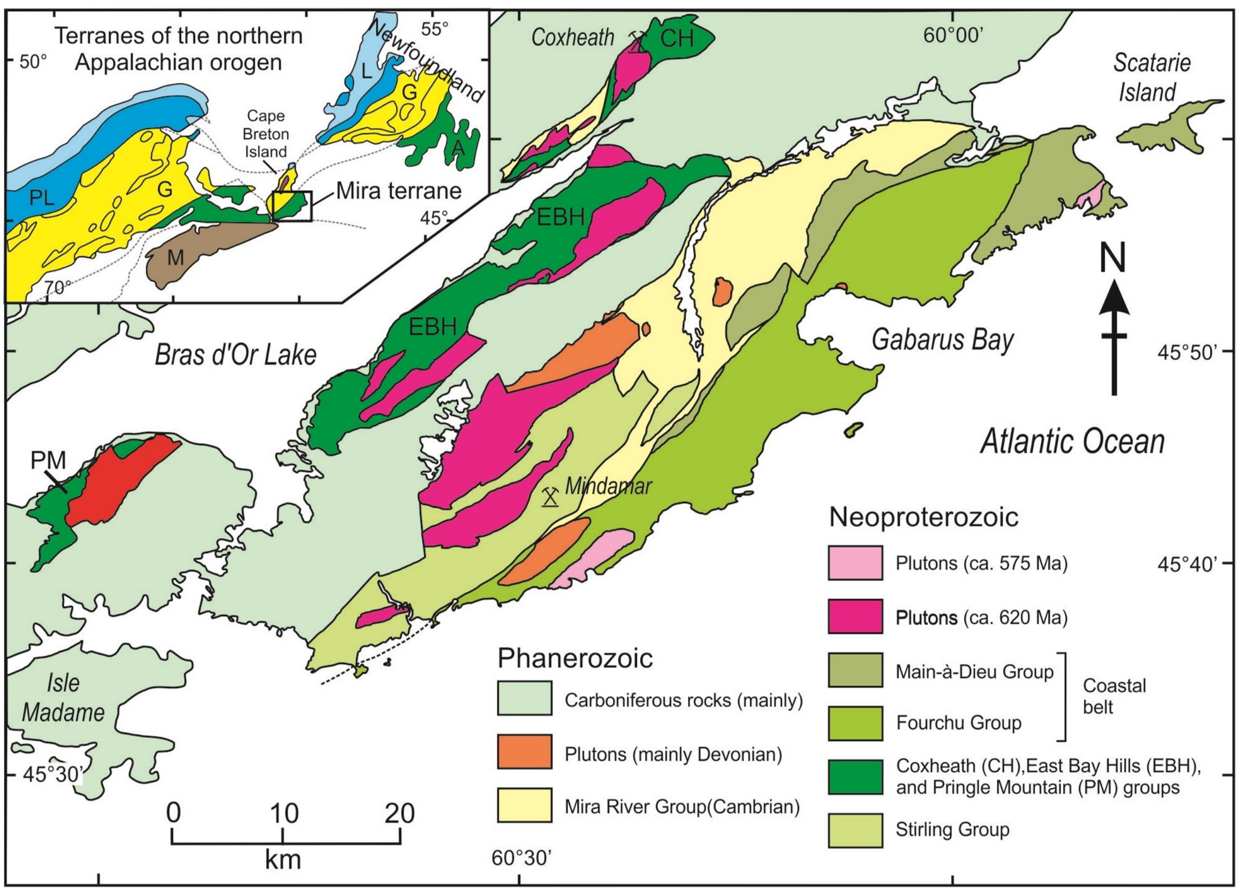

Figure 1. Simplified geological map of southeastern Cape Breton Island redrawn from Barr et al. (1996). Inset map of the northern Appalachian orogen (redrawn from Hibbard et al., 2006) shows the location of the study area (black box) in Avalonia (Mira terrane) of southeastern Cape Breton Island, Nova Scotia. Abbreviations: A, Avalonia; G, Gandaria; L, Laurentia; M, Meguma; PL, peri-Laurentian.

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detail, despite the greatly improved understanding of its petro-tectonic evolution that has since emerged (e.g. Barr et al. 1996).

This preliminary study is focused on metallogeny related to the multiple episodes of granitoid plutonism recognized in the Mira terrane during the late Neoproterozoic. In particular, the ca. 620 and ca. 575 to 560 episodes are recognized as prospective by comparison to recent studies of the closely analogous, age-contemporaneous Avalon zone of Newfoundland (Sparkes et al., 2005, 2016; Ferguson et al., 2014; Layne et al., 2016; Ferguson, 2017).

Geological Setting

The ca. 680 Ma Stirling Group consists primarily of andesitic to basaltic lapilli tuff interbedded with tuffaceous arenite and laminated siltstone. Barr et al. (1996) interpreted it to have formed in an extensional basin within a volcanic arc. The Stirling Group contains the historically mined Mindamar Zn-Pb-Cu-Ag-Au deposit (interpreted as an exhalative, VMS-type deposit by Miller, 1978; Barr et al., 1996; and others), as well as other stratiform zones of pyrite-rich, laminated litharenite-siltstone-chert-dolomite.

The ca. 620 Ma associations are composed mostly of granitic to granodioritic rocks and andesitic to rhyolitic tuffs and flows. Barr et al. (1996) interpreted these high-K, calc-alkaline rocks to have formed in a subduction-related convergent-margin setting. The historically mined Coxheath porphyry-style Cu(-Mo-Au) deposit is hosted by the Coxheath Group and comagmatic Coxheath Hills pluton (Barr et al., 1996). The host rock and molybdenite mineralization have been dated at 620 Ma ($^{40}Ar/^{39}Ar$) and 626 Ma ± 3 Ma (Re-Os), respectively (Kontak et al., 2008). A nearby zone of pyrophyllite alteration (Kontak et al., 2004), although not auriferous, may be a consequence of shallow high-sulphidation activity related to the Coxheath porphyry-Cu system. The geology and ore mineralization of the Coxheath deposit have been extensively documented in previous studies (Lynch and Ortega, 1997; Kontak et al., 2003; O'Sullivan and Hannon, 2007). Other less well documented occurrences of porphyry-style Cu mineralization are associated with the Sporting Mountain Pluton (Sexton, 1988).

The ca. 575 Ma Fourchu Group consists mainly of dacitic tuffs and flows, together with minor basaltic to rhyolitic tuffs and flows and tuffaceous sedimentary rocks. It was interpreted by Barr et al. (1996) to represent a volcanic-arc setting. The overlying Main-à-Dieu Group consists mainly of tuffaceous sedimentary and epiclastic rocks and minor basaltic and rhyolitic flows, interpreted by Barr et al. (1996) to have formed in an intra-arc extensional setting. The Main-à-Dieu Group is overlain with little or no time gap by Cambrian rocks of the Mira River Group.

The late Neoproterozoic parts of the Mira terrane and their magmatic associations provide favourable environments for "intrusion-related" hydrothermal ore deposits associated with granitoid plutonism and related volcanism. Epithermal Au-Ag deposits are characteristic of arc volcanism and are typically penecontemporaneous with their host rocks. Porphyry-style deposits are related to epithermal deposits in that they are closely associated with subvolcanic granitoid intrusions that may give rise to epithermal systems. Unlike epithermal deposits, however, porphyry deposits are fostered by fluids originating within and proximal to the intrusion. Skarn deposits are a subset of porphyry-style deposits where dominantly magmatic fluids have metasomatized calcareous country rock. If these same magmatic fluids separate and migrate to near surface, they may foster the primary stages of high-sulphidation-type epithermal Au deposits. Thermally driven shallow circulation of predominantly meteoric waters in intracaldera fracture zones above the intrusions may foster low-sulphidation-type precious metal deposits in this same near-surface regime.

Based on the rock types and ages, the Neoproterozoic rocks of the Mira terrane have significant potential for hydrothermal mineral deposits, especially epithermal Au(-Ag) and porphyry Cu(-Mo-Au) deposits.

Results

Host Rocks and Lithogeochemical Analyses

Representative rock samples were collected and submitted for research-grade lithogeochemical analysis, and results are summarized in Tables 1 to 3 (including UTM locations). Incompatible element diagrams are plotted in Figures 2a-d.

A sample of pyroclastic metabasalt (MTP18-22) was collected from a beachfront outcrop near Point

Table 1. Lithogeochemical analyses of samples from the Mira terrane — locations, descriptions and major element data

Sample	Unit	Rock type	Age (Ma)[1]	Easting[2]	Northing[2]	SiO_2 %	Al_2O_3 %	$Fe_2O_3^{(T)}$ %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	LOI %	Total %
Detection limit	--	--	--	--	--	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01		0.01
MTP18-1	Coxheath-Blue Dyke	Basalt porphyry (amygdaloidal)	--	704237	5107320	51.09	16.87	8.81	0.22	6.79	6.20	3.53	0.77	0.83	0.13	5.15	100.40
MTP18-4	Coxheath-fine-grained wallrock	Silicified wallrock	--	704134	5107335	78.04	7.72	2.91	0.08	0.94	2.82	0.09	2.01	0.35	0.05	4.29	99.29
MTP18-8	Coxheath-medium-grained diorite	Diorite - epidotized	620	704169	5107263	58.01	17.74	6.62	0.14	3.47	5.47	3.68	2.11	0.79	0.18	1.95	100.20
MTP18-11B	East Bay Hills Coxheath Rhyolite Quarry	Rhyolite porphyry (plagioclase, phyric)	623	711788	5096630	70.73	14.05	2.19	0.09	0.22	1.28	4.87	3.79	0.38	0.09	1.79	99.48
MTP18-11C	East Bay Hills Coxheath Rhyolite Quarry	Rhyolite porphyry (glassy)	623	711788	5096630	74.09	12.80	1.31	0.05	0.14	0.81	4.32	3.81	0.16	0.03	1.04	98.56
MTP18-12	Main-á-Dieu Wind Turbine	Rhyolite porphyry (spherulitic)	575-560	(274782)[2]	(5097534)[2]	74.61	13.00	2.45	0.09	0.35	0.88	6.10	1.43	0.35	0.09	0.59	99.94
MTP18-13	Big Hill Road Quarry	Epiclastic - pyritiferous	575-560	724389	5096063	61.90	15.57	7.10	0.10	1.62	3.24	5.91	0.36	0.87	0.16	3.75	100.60
MTP18-14	Big Hill Road Quarry	Epiclastic - hematitic	575-560	724389	5096063	70.09	14.55	3.37	0.09	0.61	2.10	2.96	2.96	0.45	0.12	3.13	100.40
MTP18-15A	Belfry Beach	Rhyolite	575-560	717233	5071619	76.17	12.34	1.98	0.08	0.25	1.02	5.17	1.73	0.28	0.04	0.47	99.53
MTP18-18	Sporting Mountain Pluton	Granitoid - sericitized/ carbonatized	620	663979	5069248	75.20	10.91	2.20	0.08	0.66	2.64	2.09	2.18	0.23	0.06	3.27	99.52
MTP18-19	Highway Roadcut	Rhyolite porphyry - deformed/hematitized	--	676077	5073994	72.39	13.91	2.43	0.06	0.62	0.96	4.91	2.70	0.27	0.07	1.00	99.32
MTP18-21	Irish Cove Quarry	Granitoid - epidotized	619	681343	5075678	66.82	15.36	4.20	0.08	1.78	2.30	4.10	3.70	0.58	0.13	1.53	100.60
MTP18-22	Beachfront Stirling Metabasalt	Mafic pyroclastic (amygdaloidal)	680	681036	5051352	60.51	13.10	7.50	0.16	4.11	5.31	3.57	0.19	0.43	0.05	5.28	100.20
MTP18-23	Brook/Road (Grand River)	Granitoid	575-560	683217	5055139	77.04	11.72	1.53	0.04	0.60	0.79	6.08	0.16	0.28	0.07	0.67	98.98
MTP18-25	Highway Roadcut (Chisholm Brook)	Granitoid (granophyric)	620	689437	5070389	70.63	14.84	2.85	0.09	1.00	0.90	4.62	3.03	0.39	0.11	1.43	99.87

All lithogeochemical data in Table 1 was generated using Actlabs package Litho4Res (www.actlabs.com).

1. Age (Ma) is estimated age from literature as cited in text.
2. All UTM co-ordinates are in zone 20T, except for MTP18-12, which is in zone 21T.

Table 2. Lithogeochemical analyses of samples from the Mira terrane — trace element data.

Sample	Unit	Sc ppm	Be ppm	V ppm	Cr ppm	Co ppm	Ni ppm	Cu ppm	Zn ppm	Ga ppm	Ge ppm	As ppm	Rb ppm	Sr ppm	Y ppm	Zr ppm	Nb ppm	Mo ppm	Ag ppm	In ppm	Sn ppm	Sb ppm	Cs ppm	Ba ppm
Detection limit	--	1	1	5	20	1	20	10	30	1	0.5	5	1	2	0.5	1	0.2	2	0.5	0.1	1	0.2	0.1	2
MTP18- 1	Coxheath-Blue Dyke	34	< 1	248	190	27	300	50	220	17	2.1	8	23	400	15.5	64	1.3	< 2	< 0.5	0.1	1	0.8	3.9	422
MTP18- 4	Coxheath- fine-grained wallrock	8	< 1	52	40	7	< 20	< 10	< 30	9	0.9	5	85	40	20.3	78	3.9	2	< 0.5	< 0.1	1	1.1	4.9	278
MTP18- 8	Coxheath- medium-grained diorite	15	1	138	20	19	20	60	90	19	1.0	13	67	643	14.3	118	5.2	< 2	< 0.5	0.1	1	0.7	4.4	716
MTP18- 11B	East Bay Hills Coxheath Rhyolite Quarry	6	2	17	20	1	< 20	< 10	70	14	0.8	24	114	106	40.9	223	5.8	< 2	0.8	0.1	2	2.5	4.1	1183
MTP18- 11C	East Bay Hills Coxheath Rhyolite Quarry	3	2	5	20	1	< 20	< 10	40	14	1.1	10	124	48	29.6	98	5.5	< 2	< 0.5	< 0.1	1	0.5	4.0	855
MTP18- 12	Main-á-Dieu Wind Turbine	9	< 1	9	30	2	< 20	< 10	70	13	1.5	< 5	16	90	38.0	144	2.5	< 2	< 0.5	0.1	1	0.2	0.4	521
MTP18- 13	Big Hill Road Quarry	25	< 1	136	30	15	< 20	70	100	14	0.7	< 5	9	420	24.9	89	2.0	< 2	< 0.5	0.1	1	0.3	1.0	201
MTP18- 14	Big Hill Road Quarry	16	1	16	< 20	2	< 20	< 10	40	16	1.0	< 5	93	324	37.0	138	3.4	< 2	< 0.5	0.1	1	0.3	7.0	631
MTP18- 15A	Belfry Beach	12	1	< 5	< 20	1	< 20	< 10	40	14	1.0	< 5	29	132	47.6	160	2.9	2	< 0.5	0.1	2	< 0.2	0.4	572
MTP18- 18	Sporting Mountain Pluton	3	< 1	28	30	2	< 20	10	80	12	0.7	< 5	79	163	4.9	74	1.9	3	< 0.5	< 0.1	< 1	0.4	3.7	635
MTP18- 19	Highway Roadcut	3	1	19	< 20	2	< 20	< 10	40	12	1.0	< 5	72	192	12.2	136	4.4	< 2	< 0.5	< 0.1	1	0.8	3.3	718
MTP18- 21	Irish Cove Quarry	10	1	69	30	9	< 20	< 10	40	15	0.8	< 5	129	228	23.3	202	6.0	< 2	< 0.5	< 0.1	1	0.4	1.6	784
MTP18- 22	Beachfront Stirling Metabasalt	31	< 1	224	30	24	< 20	100	90	12	1.2	6	3	141	7.4	21	0.3	< 2	< 0.5	< 0.1	< 1	< 0.2	0.4	103
MTP18- 23	Brook/Road (Grand River)	12	< 1	10	30	2	< 20	< 10	< 30	14	1.0	< 5	3	57	26.0	98	2.1	2	< 0.5	0.1	4	< 0.2	0.1	66
MTP18- 25	Highway Roadcut (Chisholm Bk)	6	2	22	< 20	3	< 20	< 10	160	15	0.9	< 5	82	189	23.8	167	5.4	2	0.5	< 0.1	1	0.4	3.4	850

Table 3. Lithogeochemical analyses of samples from the Mira terrane — REEs and additional trace element data.

Sample	Unit	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm	Hf ppm	Ta ppm	W ppm	Tl ppm	Pb ppm	Bi ppm	Th ppm	U ppm
Detection limit		0.05	0.05	0.01	0.05	0.01	0.005	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.002	0.1	0.01	0.5	0.05	5	0.1	0.05	0.01
MTP18- 1	Coxheath-Blue Dyke	10.6	23.1	3.07	12.9	3.06	0.952	3.22	0.48	2.76	0.57	1.66	0.241	1.62	0.258	1.8	0.14	0.9	0.17	8	< 0.1	2.29	0.61
MTP18- 4	Coxheath- fine-grained wallrock	16.7	35	4.2	16.3	3.76	0.96	3.26	0.56	3.51	0.69	2.06	0.311	2.06	0.344	2	0.47	1.1	0.39	6	< 0.1	4.9	1.14
MTP18- 8	Coxheath- medium-grained diorite	21.9	43.7	5.14	20.1	4.01	1.13	3.41	0.46	2.62	0.52	1.53	0.217	1.3	0.206	3.4	0.29	1.1	0.34	9	< 0.1	7.01	1.63
MTP18- 11B	East Bay Hills Coxheath Rhyolite Quarry	44.4	89.2	10.6	42.5	7.91	1.91	6.83	1.22	7.2	1.45	4.26	0.682	4.29	0.603	4.9	0.56	1.7	0.91	9	0.1	13.9	3.32
MTP18- 11C	East Bay Hills Coxheath Rhyolite Quarry	26.9	58.5	6.05	21.2	4.19	0.599	3.92	0.71	4.64	1	3.18	0.482	3.52	0.577	3.3	0.6	0.5	0.63	11	0.1	15.1	3.03
MTP18- 12	Main-á-Dieu Wind Turbine	15.9	37.6	4.99	22.6	5.58	1.12	5.7	0.96	6.14	1.37	4.17	0.638	4.62	0.711	3.7	0.28	< 0.5	0.17	6	< 0.1	3.32	0.84
MTP18- 13	Big Hill Road Quarry	11.4	25.8	3.57	15.9	4.11	1.33	4.38	0.74	4.39	0.91	2.59	0.399	2.63	0.42	2.6	0.16	< 0.5	0.06	20	< 0.1	1.83	0.48
MTP18- 14	Big Hill Road Quarry	15.8	34.4	4.42	20.3	5.1	1.09	4.7	0.89	5.94	1.38	4.18	0.645	4.54	0.724	3.5	0.36	0.9	0.4	6	0.1	3.86	0.69
MTP18- 15A	Belfry Beach	20.6	47	6.45	29.7	7.42	1.6	7.66	1.29	7.97	1.71	5.02	0.75	5.13	0.842	4.6	0.32	< 0.5	0.25	8	0.1	3.21	1.01
MTP18- 18	Sporting Mountain Pluton	10.6	18.3	2.13	8.12	1.34	0.249	1.09	0.17	0.9	0.17	0.5	0.077	0.51	0.077	2.2	0.26	1.3	0.4	8	0.2	4.74	0.75
MTP18- 19	Highway Roadcut	30.1	54.7	5.47	16.9	3.12	0.681	2.11	0.33	2.1	0.43	1.38	0.227	1.59	0.25	3.4	0.56	0.9	0.45	11	< 0.1	14.1	3.23
MTP18- 21	Irish Cove Quarry	32.9	62.9	7.23	26.5	5.13	1.14	4.47	0.66	3.84	0.77	2.4	0.358	2.31	0.376	5	0.49	0.7	0.67	8	< 0.1	15.1	3.02
MTP18- 22	Beachfront Stirling Metabasalt	2.07	4.58	0.6	2.77	0.73	0.305	0.94	0.19	1.23	0.25	0.76	0.122	0.7	0.084	0.6	0.08	0.5	< 0.05	< 5	< 0.1	0.54	0.19
MTP18- 23	Brook/Road (Grand River)	7.83	17	2.2	9.69	2.47	0.784	2.77	0.56	3.91	0.89	3.01	0.503	3.14	0.457	2.3	0.22	0.5	< 0.05	< 5	< 0.1	2.02	0.54
MTP18- 25	Highway Roadcut (Chisholm Bk)	34.7	58.7	8.01	30.8	5.81	1.26	4.73	0.72	4.23	0.87	2.46	0.395	2.73	0.436	3.6	0.48	0.8	0.4	6	0.1	11.4	1.83

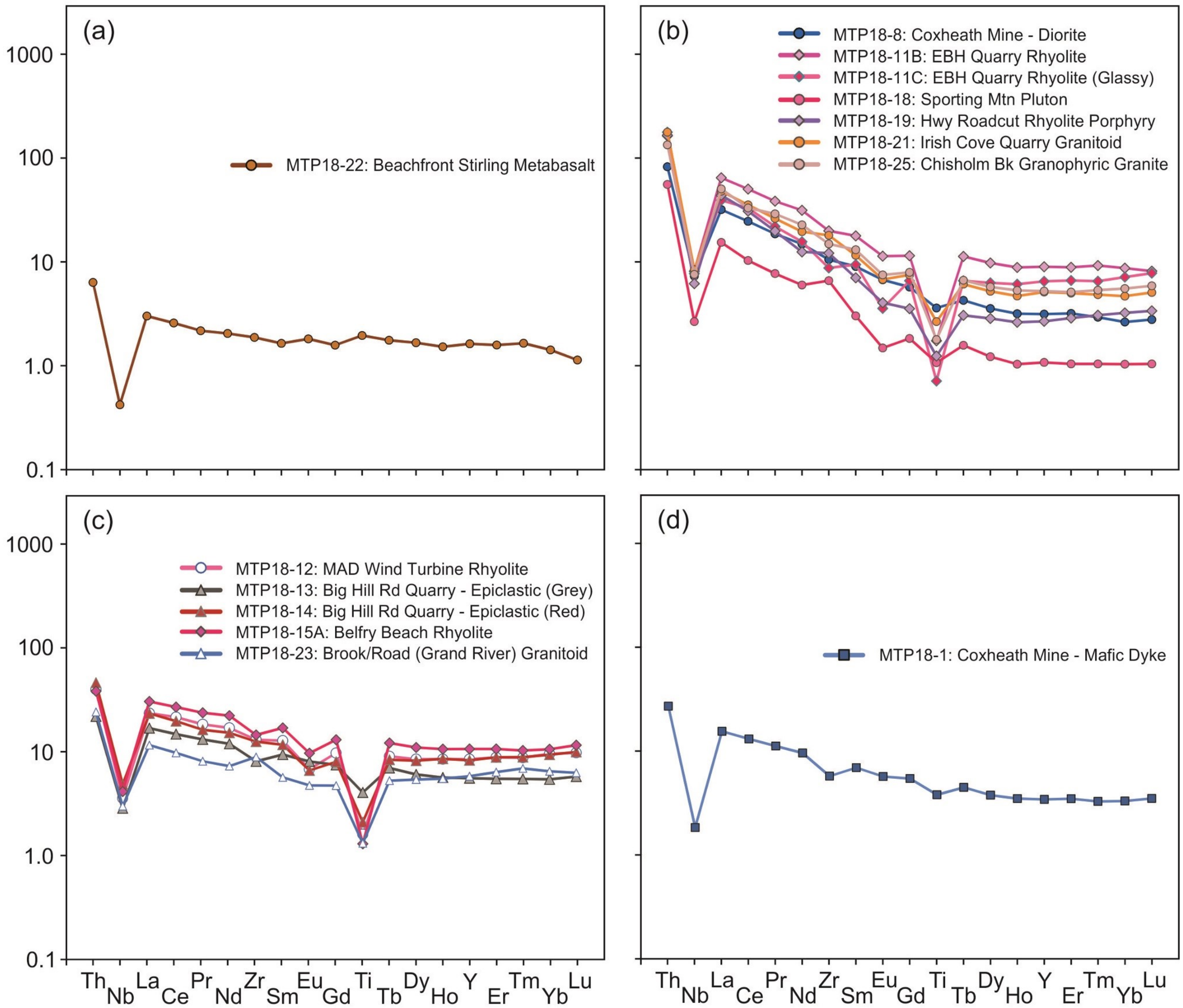

Figure 2. Incompatible element plots. (a) a ca.680 Ma sample; (b) ca.620 Ma samples; (c) ca.575 Ma samples; and (d) a post-575 Ma sample.

Michaud in an area mapped as Stirling Group (ca. 680 Ma). The incompatible element pattern (Fig. 2a) is flat and approaching 1x chondrite abundance and exhibits a negative Nb anomaly. These features are consistent with the interpretation of Barr et al. (1996) that the Stirling Group formed in an extensional basin within a volcanic arc. The Stirling Group is not considered highly prospective for porphyry- and epithermal-style precious metal deposits, but this sample provides a useful reference for discriminating the Stirling Group from younger rocks in the Mira terrane.

Seven samples were collected from rock units currently considered to have ages of ca. 620 Ma. A diorite sample (MTP18-8) from the Coxheath Hills pluton was collected immediately adjacent to the former Coxheath Mine site. Samples MTP18-11B and -11C were collected from two rhyolite phases in a quarry in the East Bay Hills Group, and rhyolite porphyry sample MTP18-19 was collected from a roadcut on Highway 4 between Johnstown and Irish Cove. Samples of granitoid plutonic rocks were taken from quarries and roadcuts at Sporting Mountain (MTP18-18), Irish Cove (MTP18-21), and Chisholm Brook (MTP-18-25). All seven samples show negative Nb and Ti anomalies and combined steep LREE/flat HREE patterns, compatible with an origin from magmatism in a continental arc (Fig. 2b). The relatively lower absolute abundance of incompatible elements in Sporting Mountain sample MTP18-18 reflects, at least in part, dilution by pervasive carbonate (sericite) alteration.

Four samples were collected of rocks currently considered to be ca. 575 to 560 Ma. They include spherulitic rhyolite from the wind turbine installation at Main-à-Dieu (MAD; MTP18-12) and sparsely phyric rhyolite from a beachfront exposure at Belfry Beach (MTP18-15A). Also analyzed in this sample set were two examples of coarse epiclastic sedimentary rock collected from the Big Hill Road Quarry near Albert Bridge: one a grey silicified/pyritized facies (MTP18-13) and the other a red hematitic facies (MTP18-14). All four samples show similar incompatible element patterns (Fig. 2c), that is, negative Nb and Ti anomalies and shallow LREE/flat HREE geometry. These patterns are also compatible with origin during volcano-plutonism in a continental arc. However, the negative slope of the LREEs is definitively shallower than that for the ca. 620 samples, and Figures 2b and 2c thus provide a basis for discriminating these two age groups in subsequent studies. Further, the similarity of the Big Hill Road epiclastic rocks strongly supports the interpretation that they were penecontemporaneously derived from ca. 575 to 560 Ma volcanic rocks.

Sample MTP18-1 was collected from an amygdaloidal mafic dyke (51.06 weight percent SiO_2) that crosscuts the Coxheath Hills diorite adjacent to the former Coxheath mine site. It is tentatively interpreted to represent a post-575 Ma episode of intrusive activity, based on the broad resemblance of its incompatible trace-element pattern (Fig. 2d) to ca. 566 Ma intermediate dykes in the vicinity of the Big Easy prospect in Newfoundland (Ferguson, 2017).

In summary, these four episodes of volcano-plutonism appear to have distinctive features on incompatible element plots (Fig. 2a-d) and these features are thus potentially useful in distinguishing age belts within the Mira terrane.

Occurrences of Mineralization

Epithermal vein systems eluded recognition in the Newfoundland Avalon zone until quite recently (by and large the 1990s) as they can be cryptic during grassroots exploration and prospection. For example, some styles of low-sulphidation veins (e.g. low-vein density peripheral occurrences) can go unrecognized as such during prospection. High-sulphidation systems can have substantial volumes of relatively Au-barren alteration surrounding a smaller auriferous core.

During the 2018 field work, several zones of altered and/or mineralized rock were encountered and assessed. Samples from these zones were submitted for high-quality exploration geochemical analysis. Four of these localities returned values for Au, Ag, and/or related pathfinder metals that are considered informative in terms of a regional metallogenic study. The results for these localities are summarized in Table 4 (including UTM locations) and are described below.

Andesite Quarry

This quarry, located off Coxheath Road approximately 7 km southwest of the former Coxheath Mine, is predominantly in andesite porphyry. Many parts of the bedrock exposed in the quarry show intense epidote-rich propylitic alteration, accompanied by greenish copper gossans consequent to weathering of small anastomosing veins of copper sulphide minerals. A grab sample of chalcopyrite-(bornite-)rich angular float (MTP18-9-2) from the quarry returned 501 ppb Au and 3.1 ppm Ag, as well as anomalous concentrations of Pb, Zn, Bi, Sb and Se, and >1 weight percent Cu. Taking into account the intermediate volcanic host/protolith and the style and ore assemblage of the veining, this showing has the characteristics of porphyry-style Cu-Au mineralization.

Sporting Mountain — Main Quarry

This quarry, off West Bay Road near Urquharts Pond, exposes volcanic rocks of the Pringle Mountain Group. The dominant rock type appear to be felsic volcanic rocks (rhyolite). Several zones of alteration, each several metres in width, cross the quarry walls. A sample of highly siliceous, pyritiferous rock (MTP18-17A1) from one of these altered zones returned 11 ppb Au and 1.1 ppm Ag, as well as anomalous concentrations of Cu, Bi, and Se. The sample is mainly composed of fine- and coarse-grained quartz, sericite, and pyrite, as well as very minor rutile. It bears textural resemblance to remineralized “vuggy silica” from some high-sulphidation epithermal deposits.

Big Hill Road Quarry

The peripheral area of an operating commercial quarry off Big Hill Road near Albert Bridge was

Table 4. Analyses of mineralized samples from the Mira terrane.

Sample	Unit	Rock type	Easting	Northing	Au ppb	Ag ppm	As ppm	Cd ppm	Cu ppm	Mn ppm	Mo ppm	Ni ppm	Pb ppm	Zn ppm
					INAA	MULT INAA/ AR-ICP	INAA	AR-ICP	AR-ICP	AR-ICP	AR-ICP	MULT INAA/ AR-ICP	AR-ICP	MULT INAA/ AR-ICP
Detection Limit	--	--	--	--	5	0.2	2	0.5	1	2	2	1	2	1
MTP18-9-1	Andesite Quarry	Propylitic altn; py-rich	702138	5101480	< 5	< 0.2	6	< 0.5	**59**	1110	< 2	18	**263**	**106**
MTP18-9-2	Andesite Quarry	Propylitic altn; cpy(brown)-rich			**501**	**3.1**	12	< 0.5	**>10000**	406	4	45	**42**	**55**
MTP18-17A1	Sporting Mountain-Main Quarry	Qz-Ser-Rut-(Chalced); minor py	661618	5069570	**11**	**1.1**	7	< 0.5	**35**	25	8	2	23	3
MTP18-17A2	Sporting Mountain-Main Quarry	Qz-Ser; 15% py			< 5	0.4	3	< 0.5	**25**	23	< 2	< 1	3	3
MTP18-17B	Sporting Mountain-Main Quarry	Hm-chlor altn (rhy protolith?);10% hm(py)			< 5	< 0.2	4	< 0.5	8	39	< 2	< 1	3	4
MTP18-17C	Sporting Mountain-Main Quarry	Qz-ser-rut-(chalced); 10% py			< 5	< 0.2	4	< 0.5	6	31	< 2	< 1	< 2	5
MTP18-17D	Sporting Mountain-Main Quarry	Qz-ser; 0% py			< 5	< 0.2	3	< 0.5	7	48	< 2	4	< 2	8
MTP18-26A1	Park Brook Au Prospect	Sericitized rhy; 25% py	696675	5092101	**33**	**1.2**	12	< 0.5	9	25	2	1	24	< 1
MTP18-26A3	Park Brook Au Prospect	Sericitized rhy; 15% py			**45**	**1.2**	25	< 0.5	11	43	**34**	1	15	< 1
MTP18-26B1	Park Brook Au Prospect	Sericitized rhy; 20% py	696675	5092101	**24**	0.3	19	< 0.5	7	52	< 2	1	5	8
MTP18-26B2	Park Brook Au Prospect	Chlor-ser intermediate; qz vein with trace py (martitized)			**88**	< 0.2	3	< 0.5	**26**	989	< 2	11	< 2	**183**
MTP18-26B3	Park Brook Au Prospect	Sericitized rhy; 10% py			**37**	< 0.2	11	< 0.5	**39**	32	5	2	6	2
MTP18-26C	Park Brook Au Prospect	Sericitized rhy; 15% py	696676	5092146	**45**	0.2	13	< 0.5	**50**	31	8	2	7	1

(Table 4 concludes next page.)

Table 4. *(concluded)*.

Sample	Ba ppm	Bi ppm	Ca %	Cs ppm	Fe %	Ga ppm	Ge ppm	Hg ppm	K %	Na %	Sb ppm	S %	Se ppm	Te ppm	Tl ppm	W ppm	Mass g
	MULT INAA/ AR-ICP	AR-MS	AR-ICP	MULT INAA/ AR-ICP-MS	INAA	AR-MS	AR-MS	INAA	AR-ICP	INAA	INAA	AR-ICP	MULT INAA/ AR-ICP-MS	AR-MS	AR-MS	INAA	INAA
Detection Limit	100	0.1	0.01	0.05	0.02	1	0.1	1	0.01	0.01	0.2	0.001	0.1	0.1	0.1	4	
MTP18-9-1	100	0.1	3.99	1.37	5.85	12	< 0.1	< 1	0.12	1.38	0.4	0.968	1.1	0.2	< 0.1	< 4	36
MTP18-9-2	< 100	**9.7**	5.71	0.06	8.95	21	0.4	< 1	< 0.01	0.05	**2.9**	1.537	**8.9**	2.0	< 0.1	< 4	40
MTP18-17A1	100	**2.6**	0.02	1.03	1.33	2	< 0.1	**1**	0.27	0.05	1.4	0.639	**5.9**	1.9	0.1	< 4	27
MTP18-17A2	**1100**	0.4	0.03	1.62	1.29	8	< 0.1	< 1	0.32	0.05	1.2	0.058	0.8	0.7	0.1	< 4	28
MTP18-17B	300	0.3	<0.01	1.24	3.48	7	< 0.1	< 1	0.23	0.04	1.4	0.02	0.9	< 0.1	< 0.1	< 4	31
MTP18-17C	**1900**	<0.10	0.03	2.27	1.52	14	< 0.1	< 1	0.53	0.06	1.0	0.06	0.5	< 0.1	0.2	< 4	25
MTP18-17D	200	<0.10	0.09	3.43	1.56	4	< 0.1	< 1	0.36	0.78	0.9	0.00	0.5	< 0.1	0.2	< 4	27
MTP18-26A1	< 100	**5.4**	0.21	0.61	4.48	2	< 0.1	< 1	0.18	0.13	**4.3**	3.75	**7.4**	**4.0**	0.1	< 4	29
MTP18-26A3	< 100	**3.6**	0.62	0.45	2.98	1	< 0.1	< 1	0.06	0.09	**23.8**	2.60	3.1	**8.9**	0.1	**6**	31
MTP18-26B1	< 100	1.3	0.51	0.42	5.62	3	< 0.1	< 1	0.04	0.09	**6.2**	4.40	3.0	2.8	< 0.1	**25**	27
MTP18-26B2	< 100	<0.10	0.24	1.68	4.57	8	< 0.1	< 1	0.24	0.08	**2.3**	0.01	0.5	0.4	0.2	< 4	29
MTP18-26B3	< 100	**4.0**	0.34	0.65	3.99	3	< 0.1	< 1	0.21	0.13	**5.8**	3.88	2.1	**4.0**	0.1	< 4	31
MTP18-26C	< 100	**7.3**	0.40	0.56	5.46	2	< 0.1	< 1	0.11	0.14	**6.0**	5.12	3.3	**8.5**	< 0.1	**10**	34

Abbreviations: altn = alteration, chalced = chalcedony, chlor = chlorite, cpy = chalcopyrite, hm = hematite, py = pyrite, qz = quartzite, rhy = rhyolite, rut = rutile, ser = sericite.

1. All compositional data tabled was generated using Actlabs package 1EPI-MS (www.actlabs.com).
2. Values set in bold are considered anomalous.

accessible during field work. The dominant rock types observed in that area were epiclastic sandstone and conglomerate. Constituent clasts have variable degrees of rounding and are mainly volcanic. Most of these epiclastic rocks are red (hematitic) (e.g. MTP18-14). A hard, grey facies of the epiclastic rocks is highly silicified and contains abundant fine-grained pyrite. The lithogeochemical analysis of this highly silicified facies (sample MTP18-13) returned 70 ppm Cu, 100 ppm Zn, and 20 ppm Pb (Tables 2, 3). Scanning electron microscope imaging of sample MTP18-13 confirmed that fine-grained pyrite is confined to the silicified matrix between volcanic clasts and revealed delicate (epithermal-style) overgrowths of galena on fine-grained pyrite.

With reference to the incompatible element plot of Figure 2c, the slightly more depleted (but parallel) composition of silicified sample MTP 18-13 versus hematitic sample MTP18-14 is interpreted as a simple consequence of silicification (dilution) of the former sample during induration relative to the predominant red (hematitic) facies.

The grey silicified facies at Big Hill Road quarry bears a strong resemblance to the silicified and pyritized epiclastic conglomerates that host the mineralized veins of the Big Easy low-sulphidation Au-Ag prospect in the Avalon zone of Newfoundland (Ferguson, 2017). At Big Easy this facies is interpreted as having formed at surface in sulphidic geothermal ponds, and then was subsequently crosscut (post-induration) by the precious-metal veins. Mineralization at Big Easy has been dated at ca. 575 Ma (Ferguson, 2017) making it potentially age correlative with the Big Hill Road host rocks, pending more explicit dating of these and other ca. 575 to 560 Ma rocks in the Mira terrane.

Park Brook Prospect

This prospect is listed in the Nova Scotia Mineral Occurrence Database (Nova Scotia Department of Natural Resources, 2016) as *Park Brook Au Occurrence.* It is described therein as auriferous sericite-hematite mineralization hosted in shear zones within volcanic rocks of the East Bay Hills Group (ca. 620 Ma). This prospect was explored for gold in 1986 by INCO Ltd./Scominex as part of their East Bay Hills Project (Booth, 1986).

We visited the surface showings along Park Brook that were documented in the above report and collected samples of altered/mineralized rock along the banks. The main host rock at these sites is altered, foliated rhyolite with substantial pyrite mineralization (10-25%), largely as coarse (>1 mm) spots or grain clusters. Samples of this rock (Table 4; MTP18-26A, B, C) returned values of between 33 and 45 ppb Au and up to 1.2 ppm Ag. These values are consistent with those reported by Booth (1986) from these locations. These samples also returned anomalous concentrations of Cu, Mo, Zn, Bi, Sb, Te, and W. A single sample (MTP18-26B2) that was hosted by an enclave of intermediate (pyroclastic) volcanic rock and that contained a small pyritiferous quartz vein returned 88 ppb Au. The hematite in all these samples is a consequence of later martitization (weathering) of the original pyrite. The predominant alteration phase is a sericite.

The style of mineralization/alteration in these rocks is equivocal (at least at the showings visited) in terms of characterizing this occurrence as epithermal (versus orogenic).

Summary and Conclusions

The lithogeochemical sampling and analysis accomplished during this study has provided a starting point for further assessing and subdividing rock types in the Mira terrane, especially those in the ca. 620 and ca. 575 to 560 Ma belts. Three locations discovered during the relatively brief initial field campaign are anomalous for Au and pathfinder metals, as well as displaying alteration typically associated with epithermal- or porphyry-style mineralization. Further work is planned to follow up on the positive implications of these findings for mineral exploration within the Mira terrane.

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