Sulphide Mineralization at the Core Shack and Galena Mine Occurrences, Chéticamp Area, Cape Breton Island, Nova Scotia

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Introduction

The Chéticamp area of Cape Breton Island, Nova Scotia, is located in the western part of the Ganderian Aspy terrane (Fig. 1) and has been an exploration target for economic mineral since the 1890s (e.g. Sangster et al., 1990; DeMont 1992). The units that host these Cu-Pb-Zn mineral occurrences are part of the Jumping Brook Metamorphic Suite (Jamieson et al., 1989; Barr et al., 1992). In recent work (e.g. White et al., 2017), the stratigraphic units in the Jumping Brook Metamorphic Suite have been simplified to consist of the dominantly metavolcanic Faribault Brook Formation and the overlying, dominantly metasedimentary Dauphinee Brook Formation (Fig. 1).

Based on U-Pb zircon ages (White et al., 2016) and geochemical studies (Tucker 2011; Shute 2017; Vibert 2018; Hooey 2019), the ca. 530 to 490 Ma Jumping Brook Metamorphic Suite has MORB-like characteristics that suggest correlation with Newfoundland's Exploits subzone and related volcanic massive sulphide and gold deposits (Rogers et al., 2006; Galley et al., 2007; van Staal, 2007; McNicoll et al., 2010).

This report summarizes a detailed petrographic and lithogeochemical study on mineralized samples collected from the Core Shack and Galena Mine occurrences in the Dauphinee Brook Formation.

Field Relations

The Faribault Brook Formation forms the lower part of the Jumping Brook Metamorphic Suite and is dominantly a mafic metavolcanic package, but includes less abundant intermediate and felsic metavolcanic rocks and minor metasedimentary rocks (Jamieson et al., 1989; White et al., 2015). The Dauphine Brook Formation forms the upper part of the Jumping Brook Metamorphic Suite and is dominantly metasedimentary. The contact between the two is interpreted to be gradational (White et al., 2015, 2017). A more detailed description of the various rock types in these formations is in White et al. (2015).

Detailed mapping confirmed that most of the documented mineralization occurs near the contact between the Faribault Brook and overlying Dauphinee Brook formations (White et al., 2015, 2016, 2017). The Core Shack and Galena Mine occurrences are near the lower part of the Dauphinee Brook Formation and are associated with a distinctive, pale muscovite-garnet schist with quartz eyes (Connors 1986; Tucker 2011; White et al., 2015). This muscovite-garnet schist is interlayered with phyllite, metawacke, and quartzite.

At both locations, mineralization occurs as lenses and pods, typically 3 to 10 cm thick and 5 to 30 cm long. They are concordant with the main schistosity and are typically boudinaged and elongated parallel to the well developed regional mineral lineation, which plunges shallowly to the north-northwest. This concordancy confirms an origin that predates metamorphism and deformation (Lynch and Mengel, 1995; White et al., 2015, 2016). The presence of a younger set of sulphide-bearing, deformed quartz veins suggests a later remobilization of quartz and sulphide minerals (e.g. Hooey 2019).

Sulphide Petrography

Introduction

Three samples (CW18-060A, B, C) were collected from the Core Shack occurrence (UTM in NAD83:

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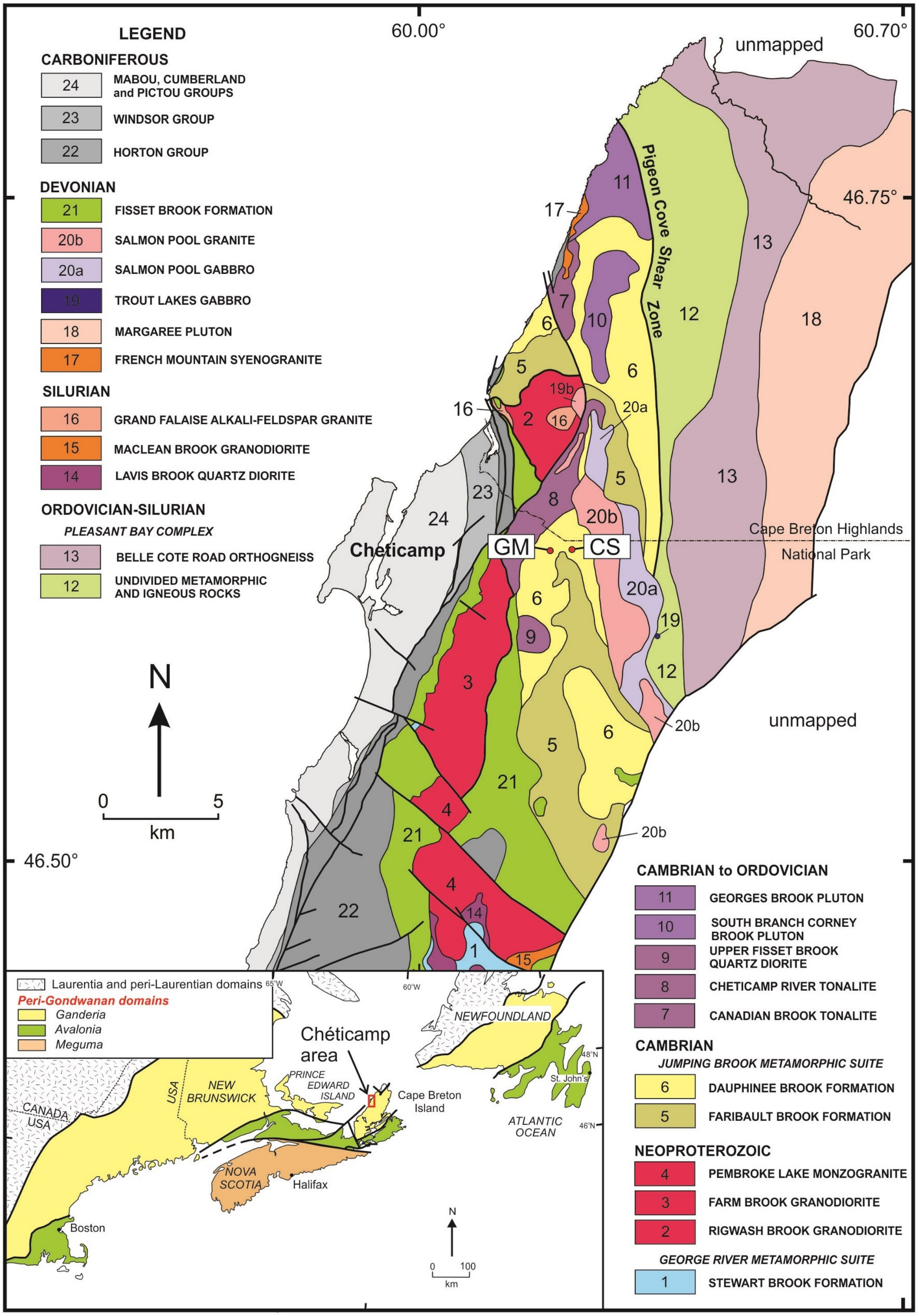

Figure 1. Geological map of the Chéticamp area (after White et al., 2017) showing the locations of the Core Shack (CS) and Galena Mine (GM) occurrences. Inset map of the northern Appalachian orogeny (redrawn from Hibbard et al., 2006) shows the location of the study area (red box) in Ganderia (Aspy terrane) of western Cape Breton Island, Nova Scotia.

E=659768, N=5165207): one from each of three different 5 cm thick mineralized layers within a 5 to 6 m wide muscovite-garnet schist unit. Eight samples were collected from the Galena Mine occurrence: one sample (15GB0380; UTM in NAD83: E = 658922, N = 5165460) from near audit #2 as defined by DeMont (1992); two samples (15GB0381; UTM in NAD83: E = 658948, N = 5165431 and 15GB0382; UTM in NAD83: E = 658924, N = 5165441) from the Highlands Mercury showing approximately 20 m up stream from the previous sample; and five samples (15GB0383A, B, C, D, and E; UTM in NAD83: E = 658905, N = 5165456) from a mineralized boulders in the stream bed between the above samples.

Although the host rocks are deformed and metamorphosed, most of the sulphide mineralization, at least on a thin-section scale, appears to have retained its primary mineralogy and texture.

Core Shack Occurrence

All three samples collected from the Core Shack occurrence have similar features. They display banded, disseminated to semi-massive sulphide mineralization consisting of 15 to 35 volume % sulphide minerals (Figs. 2a-d). Arsenopyrite is the dominant sulphide mineral in all three samples, forming 0 to 30% of each. Sulphides found in lesser amounts are pyrite (1–5%), sphalerite (1–3%), chalcopyrite (trace–1%), and galena (trace–1%).

Two textural varieties of arsenopyrite are present (Fig. 2d). Type 1a (Apy1a) occurs as fine-grained (20–400 μm), weakly sieved (few inclusions), euhedral to subhedral grains that occur parallel to white mica-rich foliation (Fig. 3a). Type 1b (Apy1b) occurs as fine- to coarse-grained (10–2000 μm), subhedral, weakly to moderately sieved, fractured grains that occur in a weakly foliated granoblastic matrix of quartz and minor white mica (Fig. 3b). The percentage of Apy1a versus Apy1b in thin section varies depending on where the section was cut from the sample.

Two generations of pyrite are present. Type 1 (Py1) is interpreted as an early phase pyrite. It is fine- to coarse-grained (10–2000 μm), subhedral, moderately sieved and fractured, and is associated with Apy1b in the granoblastic quartz-rich areas (Fig. 3b). Type 2 (Py2) is a later phase pyrite that is typically fine-grained (< 100 μm) and subhedral. It occurs on the rims of all sulphide minerals, either as individual grains or as clusters, or in fractures of Apy1b (Fig. 3c).

Sphalerite is generally restricted to granoblastic quartz-rich bands, and the percentage of sphalerite is highly variable amongst individual bands (trace–5%). In bands where sphalerite is more abundant, it forms anhedral masses, which contain inclusions of Apy1b and Py1, and it also occurs along the rims and within fractures of Apy1b and Py1 (Fig. 3d). In sphalerite-poor bands, however, it occurs only along the rims and within fractures of Apy1b and Py1 (Figs. 3c, e). Chalcopyrite is generally present only in granoblastic quartz-rich bands and occurs along the rims and within fractures of Apy1b and Py1 (Figs. 3c, e). Rarely, chalcopyrite occurs on the rim of Apy1a, but only on grains at the contact between mica- and quartz-rich bands (Fig. 3c) or along grain boundaries between quartz grains. Galena is observed only along the rims and within fractures of Apy1b as 100 to 2000 μm, subhedral grains in granoblastic quartz-rich bands (Fig. 3f). Chalcopyrite is typically present in close association with galena.

Galena Mine

Samples collected from the Galena Mine occurrence have a banded appearance similar to the Core Shack occurrence but have lower abundances of sulphide minerals (5–10 volume per cent). Two varieties of mineralization are present in the samples and are referred to as MZ-1 and MZ-2.

MZ-1

MZ-1 consists of 0.5 to 1 cm thick layers of massive arsenopyrite-sphalerite-galena (Fig. 2e). The mineralization comprises sphalerite (5–8 volume per cent) and lesser proportions of arsenopyrite (2–5%), pyrite (1–3%), galena (trace–2%), and chalcopyrite (trace). Sphalerite predominately occurs as anhedral, inclusion-rich masses with indistinguishable grain boundaries (Figs. 4a, b, c) and subhedral, fairly inclusion-poor grains (Fig. 4d). Inclusions of pyrite and arsenopyrite are present in sphalerite; both are moderately to heavily fractured, and fractures are infilled in places with sphalerite (Figs. 4a, b). Arsenopyrite grains are subhedral, weakly to moderately sieved, up to 200 μm in diameter, and occur as inclusions in the sphalerite (Figs. 4a, b, c).

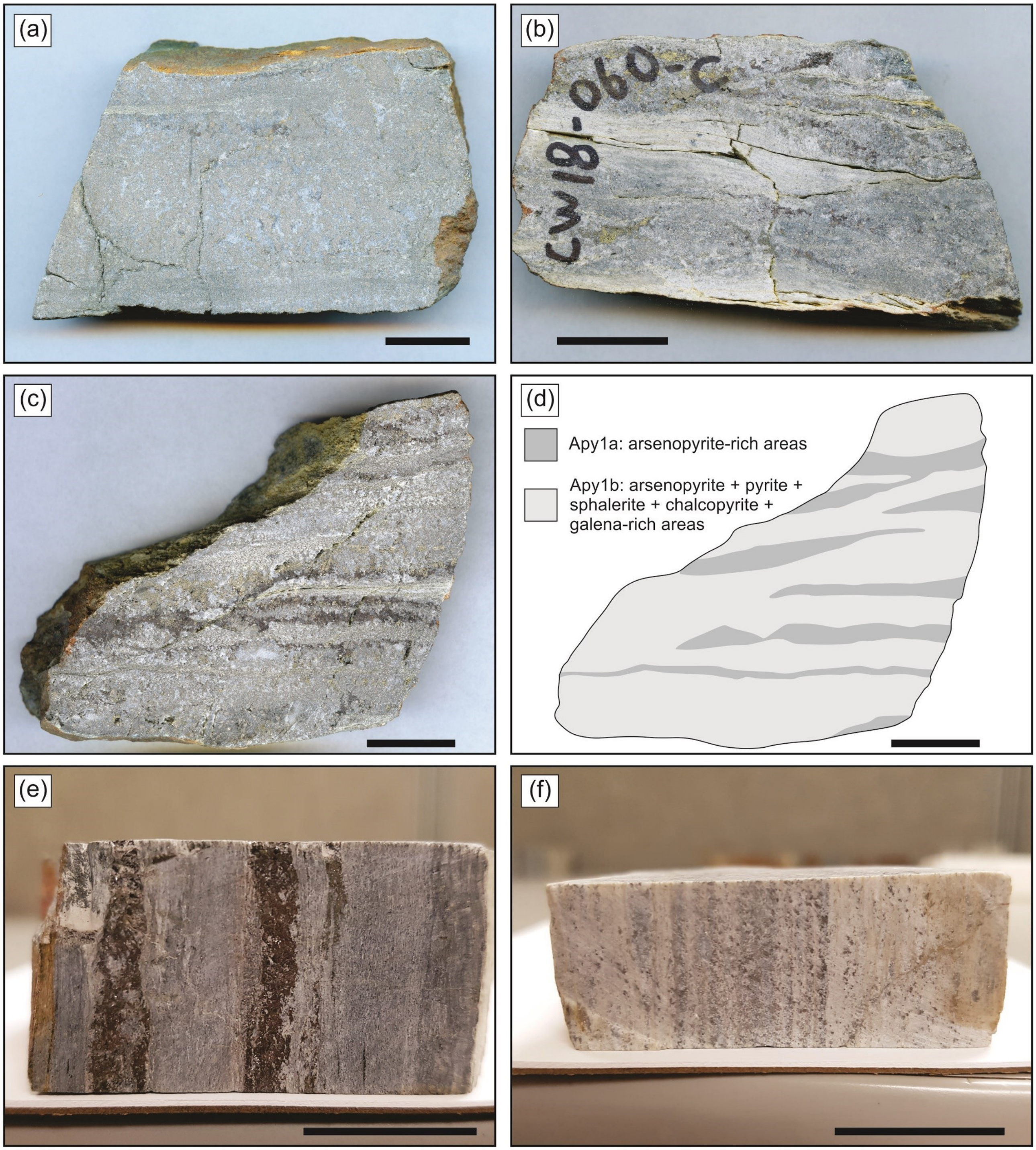

Figure 2. Slabs of sulphide mineralization from the Core Shack (a-d) and Galena Mine (e, f) occurrences. All scale bars are 2 cm. (a) Banded arsenopyrite layers up to 30-35 volume % (sample CW18-060A). (b) Weakly banded disseminated arsenopyrite-sphalerite-chalcopyrite (sample CW18-060C). (c) Semi-massive banded sulphide mineralization consisting of arsenopyrite-pyrite-sphalerite-chalcopyrite-galena (sample CW18-060B). (d) Sketch of slab in Figure 2c showing the banded nature of sulphide mineralization and the locations of the different textural variations of arsenopyrite (see petrography section for explanation). (e) Banded sphalerite-arsenopyrite representative of mineralization style MZ-1. (f) Banded arsenopyrite representative of mineralization style MZ-2.

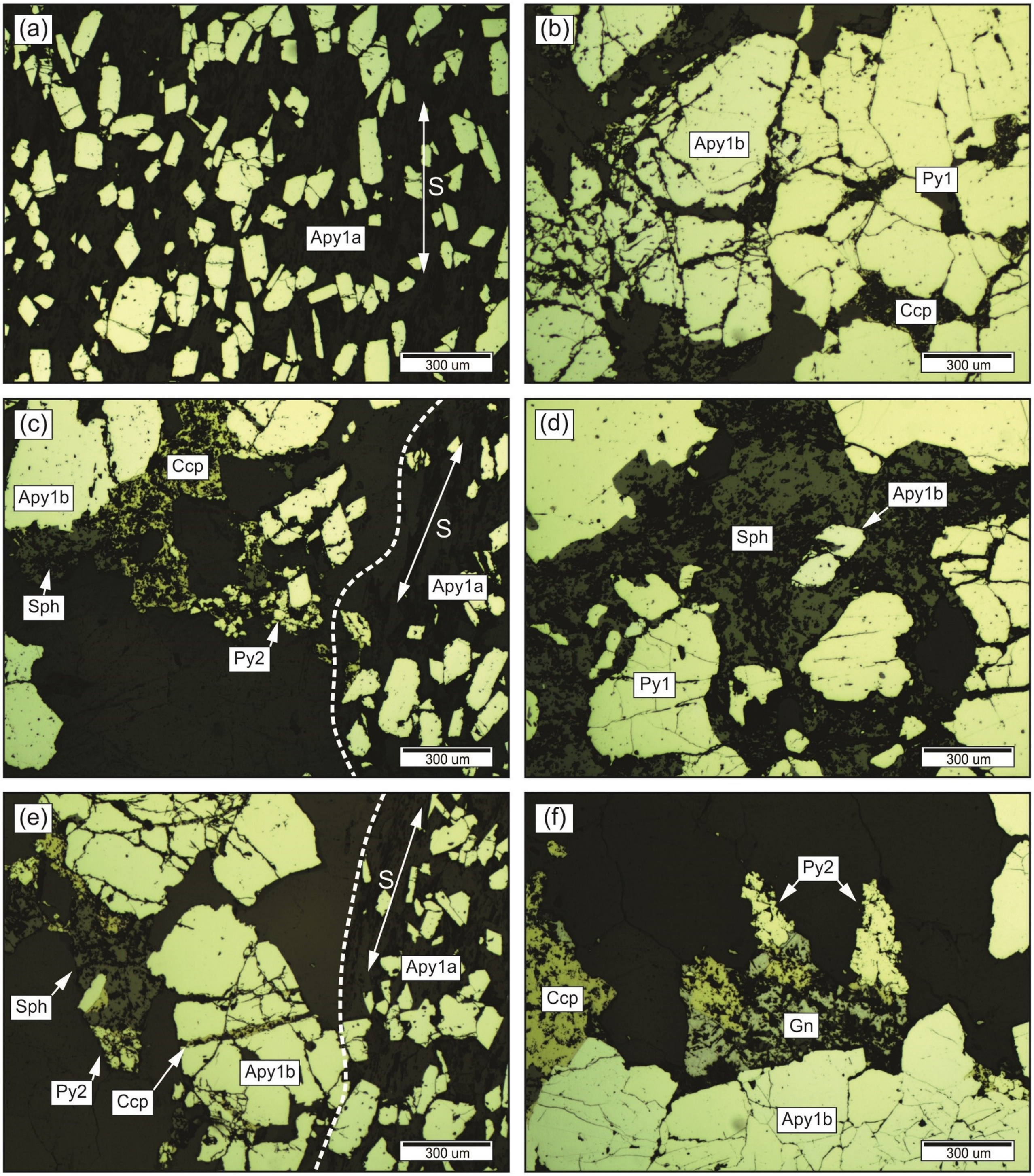

Figure 3. Representative photomicrographs of sulphide mineralization from the Core Shack occurrence. All photos were taken in reflected light. (a) Arsenopyrite style 1a (Apy1a) grains subparallel to foliation (S) in mica-rich bands. (b) Arsenopyrite style 1b (Apy1b) in contact with the early generation of pyrite (Py1). Chalcopyrite (Ccp) is fracture filling. (c) Boundary (dashed white line) between mica-rich and granoblastic quartz-rich bands. Note the difference in grain size and form between Apy1a and Apy1b. Chalcopyrite and sphalerite (Sph) occur along the edges of Apy1b. The late generation of pyrite (Py2) occurs along the edges of Apy1b and chalcopyrite. Note the difference in grain size between Py1 (in frame b) and Py2. (d) Anhedral mass of sphalerite containing inclusions of Apy1b and Py1. (e) Boundary (dashed white line) between mica-rich and granoblastic quartz-rich bands. The fracture in Apy1b is infilled with chalcopyrite. Chalcopyrite and sphalerite also occur along the grain margins of Apy1b. (f) Galena (Gn) and chalcopyrite occurring along the margins of Apy1b and Py2 occurring along the margins of galena.

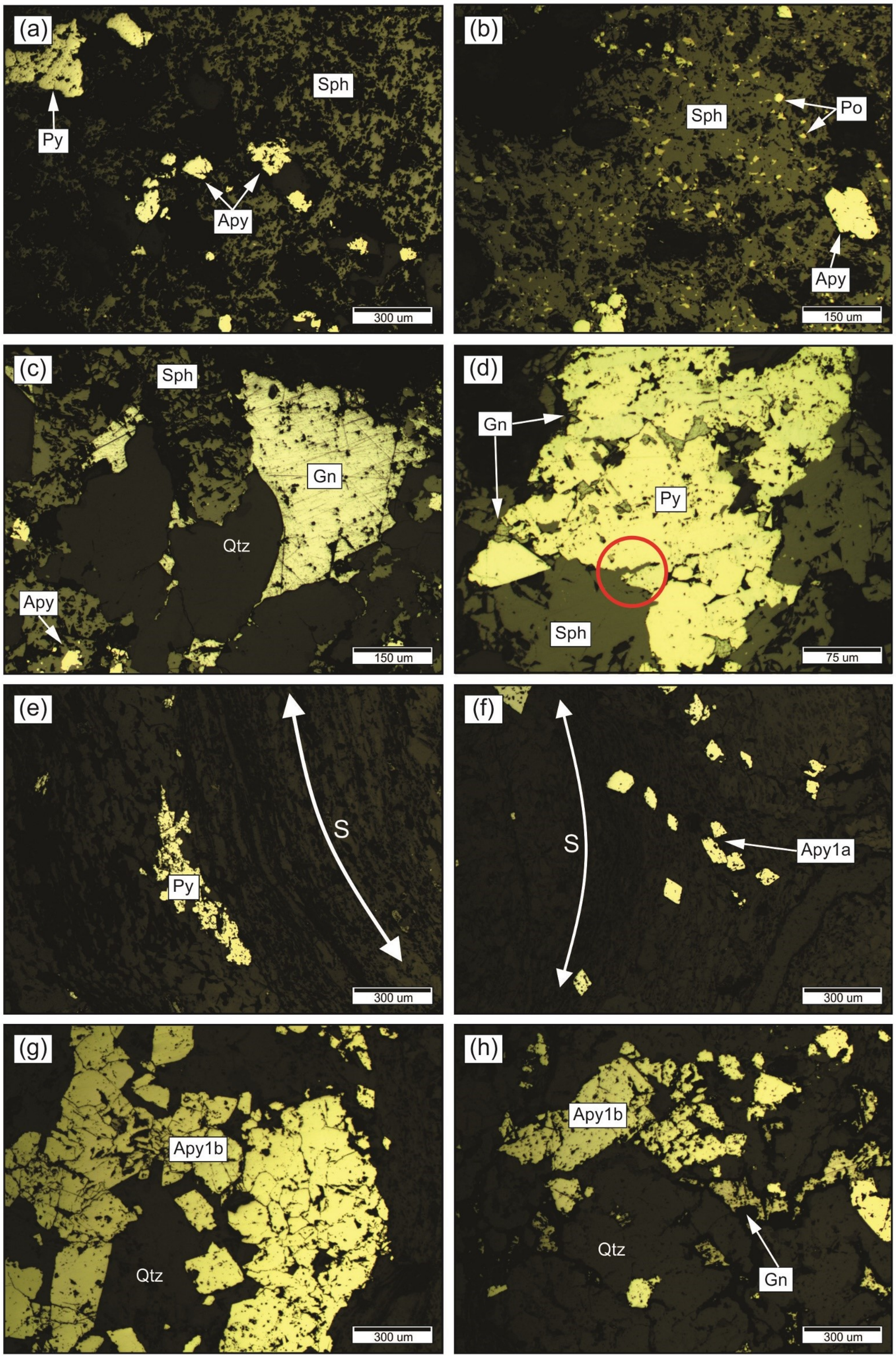

Figure 4. Representative photomicrographs of MZ-1 (a-e) and MZ-2 (f-h) sulphide mineralization in samples from the Galena Mine occurrence. All photographs were taken in reflected light. (a) Pyrite (Py) and arsenopyrite (Apy) inclusions within massive sphalerite (Sph). (b) Very fine-grained pyrrhotite (Po) blebs occurring in massive sphalerite. (c) Galena (Gn) appears to have infilled open spaces and occurs along the edges of sphalerite and quartz. (d) Large pyrite with galena occurring along the grain margins. Sphalerite infills fractures in the pyrite (red circle). (e) Elongated pyrite parallel to foliation (S). (f) Fine-grained arsenopyrite 1a (Apy1a) in mica-rich bands. (g) Medium- to coarse-grained arsenopyrite (Apy1b) and quartz (Qtz). (h) Galena occurring along grain boundaries of granoblastic quartz and in close association with Apy1b.

Pyrite grains display the same textural characteristics as arsenopyrite, but fractures in the pyrite are infilled with sphalerite (Fig. 4d). Galena typically occurs as small inclusions within pyrite (Fig. 4d), but rare, larger grains (up to 200 µm) are present along the margins of massive sphalerite and interstitial to granoblastic quartz (Fig. 4c). These larger galena grains have sharp boundaries that suggest deposition in open spaces. Trace amounts of chalcopyrite are present in close association with pyrite. Trace amounts of pyrrhotite are present as < 25 µm blebs in sphalerite (Fig. 4c). In the sphalerite-poor bands (Fig. 2e), sulphide minerals (arsenopyrite + pyrite + sphalerite + chalcopyrite) form 1 to 2 volume per cent in clusters parallel to foliation (Fig. 4e).

MZ-2

MZ-2 consists of millimetre-scale layers of arsenopyrite (Fig. 2f), which constitutes 3 to 5 volume per cent of the mineralization, and trace amounts of galena and pyrite. Arsenopyrite is fine- to medium-grained (10–800 µm), euhedral to subhedral, and weakly to moderately sieved and fractured (Figs. 4f, g, h). As at the Core Shack occurrence, two textural varieties of arsenopyrite (Apy1a, 1b) are present at the Galena Mine occurrence. Apy1a is typically associated with mica-rich bands, but in contrast to the Apy1 at Core Shack, the sulphides are not parallel to the foliation (Fig. 4f). Larger arsenopyrite grains (Apy1b) occur in clusters associated with granoblastic quartz (Figs. 4g, h). Galena is a trace phase in close association with Apy1b and interstitial to granoblastic quartz (Fig. 4h). Like galena, trace amounts of pyrite are present and occur with Apy1b.

Based on the petrographic observations, the paragenetic sequence of sulphide mineralization for the Core Shack and Galena Mine occurrence is similar and is summarized in Figure 5.

Whole Rock Geochemistry

Core Shack

Bulk rock geochemical results from three samples of banded disseminated to semi-massive sulphide mineralization from the Core Shack mineral occurrence indicate significant concentrations of base and precious metals (Table 1). Gold concentrations are relatively enriched in all three samples and range between 5.6 and 8.6 ppm (g/t) with an average value of 6.7 ± 1.6 ppm. Silver is also enriched, ranging between 26.9 and 46.0 ppm (~36.9 ± 9.6 ppm). Arsenic is above the analytical confidence limit (>1 weight per cent) in all three samples and Zn is above the analytical confidence limit (>1 weight per cent) in two of the three samples. Lead concentrations range from 1090 to 5590 ppm (~3400 ± 2250 ppm) and Cu between 620 and 7720 ppm (~3990 ± 3560 ppm). Other elements of notable enrichment include Cd (~210 ± 196 ppm), Bi (~43.2 ± 34 ppm), Sb (~489 ± 117 ppm), and Se (~2.2 ± 1.0 ppm).

Both Au and Ag have weak positive correlation with S content (Figs. 6a, b) indicating that both of these precious metals may be present within sulphide minerals as either micro- or nano-inclusions or as a solid solution in the sulphide mineral structure. Gold does not show a positive correlation with any major metal, but given the high abundance of arsenopyrite and the amount of gold that can be dissolved in its structure (~1000 ppm, Vaughan and Kyin, 2004; Fig. 6c), it is plausible that arsenopyrite is the prominent host of gold in these samples. For example, sample CW18-060-B has Au concentration of 5.6 ppm and contains ~15 volume per cent arsenopyrite. If 20 ppm Au is present in solid solution in the arsenopyrite structure, then the total Au contributed by arsenopyrite to the bulk sample would be ~5.7 ppm. Therefore, it is likely that the bulk of the Au in the Core Shack occurrence samples is hosted in arsenopyrite. Silver has a positive correlation with Pb, indicating that galena may be the main host for silver in these samples (Fig. 6d).

Galena Mine

Bulk rock geochemical results from Galena Mine samples show similar enrichments in base and precious metals as in the Core Shack occurrence samples. Gold concentrations from MZ-1 vary between 0.12 and 2.27 ppm (~1.03 ± 0.7 ppm; n = 7) and Ag ranges from 4.4 to 83.8 ppm (~25.8 ± 31.9 ppm; n = 6), with one sample having Ag above the range of the analytical confidence (>100 ppm; Table 1). Zinc is above the analytical confidence in all samples from MZ-1 (>5000 ppm) and Pb is above analytical confidence in three of seven samples (>5000 ppm). In the other four samples, Zn ranges from 260 to 590 ppm. Arsenic is also above analytical confidence (>1 weight per cent) in

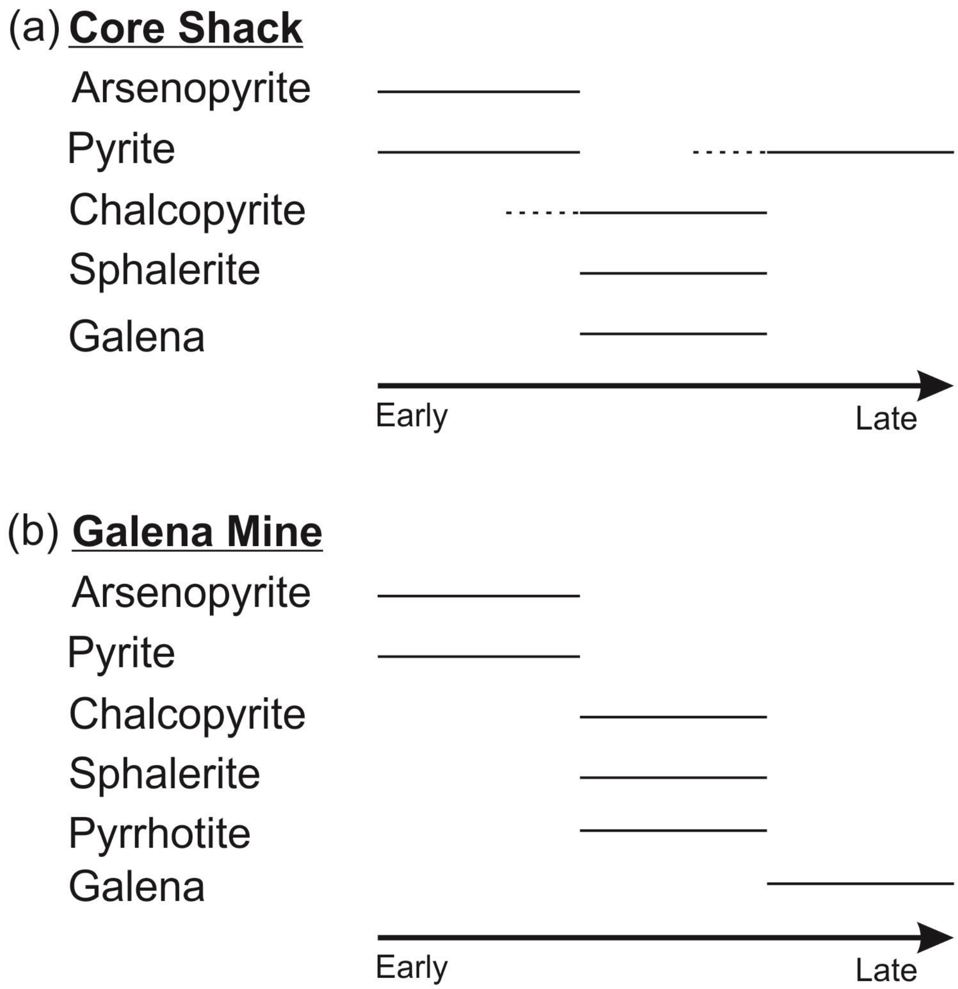

Figure 5. Sulphide mineral paragenetic sequence for the (a) Core Shack and (b) Galena Mine occurrences.

three samples, and it ranges from 1690 to 7180 ppm in the other five samples. Copper ranges from 260 to 760 ppm (~510 ± 215 ppm; n = 7). Cadmium is over analytical confidence (>1000 ppm) in two samples, both of which are also over analytical confidence in Zn and Pb. Cadmium concentration in the other samples ranges from 72 to 950 ppm. Other elements of notable enrichment include Se (~2.08 ± 1.7 ppm), Bi (~35.2 ± 59 ppm), and In (~36 ± 52 ppm).

Gold concentrations from MZ-2 range from 0.07 to 3.8 ppm (~2.29 ± 1.97 ppm; n = 3) and Ag ranges from 3.29 to 8.43 ppm (~6.17 ± 2.63 ppm; n = 3). Arsenic is over analytical confidence (>1 weight per cent) in two of three samples, and is 2420 ppm in the third. Overall, Zn and Pb have lower concentrations in MZ-2 compared with MZ-1. Copper ranges between 150 and 174 ppm (average 160 ± 12 ppm; n = 3).

It is not as evident as at the Core Shack occurrence, but there appears to be weak positive correlation of Au and Ag with S content as well as with Ag and Pb concentrations (Fig. 6). Gold does not show any correlation with any major metal but could be hosted in arsenopyrite (see above). Like the Core Shack occurrence, the highest Ag concentrations are associated with high Pb values which suggests that galena is the dominant host for Ag (Fig. 6d).

Summary

Although the geology in the Chéticamp area is structurally complex, based on field and petrographic evidence the main phase of

Table 1. Assay data from the Galena Mine and Core Shack mineral occurrences.

Sample	15GB0380[1]	15GB0381[1]	15GB0382[1]	15GB0383A[1]	15GB0383B[1]	15GB0383C[1]	15GB0383C[2]	15GB0383D[1]	15GB0383E[1]	15GB0383E[2]	CW18-060A[2]	CW18-060B[2]	CW18-060C[2]
Analysis year	2015	2015	2015	2015	2015	2015	2018	2015	2015	2018	2018	2018	2018
Location	GM-MZ-1	GM-MZ-2	GM-MZ-1	GM-MZ-1	GM-MZ-1	GM-MZ-2	GM-MZ-2	GM-MZ-1	GM-MZ-1	GM-MZ-1	CS	CS	CS
S (wt%)	8.22	0.59	0.93	3.57	3.86	3.33	3.75	2.30	3.45	3.90	13.9	15.9	10.1
Au (ppm)[a]	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	3.44	n.c.	n.c.	1.17	8.55	5.60	6.07
Au[b]	1.16	0.07	0.29	1.15	1.19	2.99	3.8	0.12	2.27	1.0	10.8	6.8	7.0
Ag	>100	3.29	8.59	83.8	43.1	8.43	6.80	9.27	5.88	4.40	37.9	46.0	26.9
Cr	7.00	17.0	22.0	10.0	14.0	7.00	n.c.	23.0	5.00	n.c.	n.c.	n.c.	n.c.
Co	22.1	12.7	11.5	45.2	45.5	63.4	76.0	14.9	20.6	23.1	20.6	13.4	12.0
Ni	2.80	14.3	12.8	10.4	15.3	1.40	1.50	24.2	1.50	1.00	2.70	6.30	1.60
Cu	478	158	434	672	729	151	174	759	239	262	616	3641	7716
Zn	>5000	3200	>5000	>5000	>5000	762	878	>5000	>5000	>10000	3766	>10000	>10000
Ga	2.97	4.30	4.34	3.52	4.18	2.14	15.1	4.97	3.76	15.5	4.10	4.40	6.60
Ge	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	2.30	n.c.	< 0.1	1.10	n.c.	n.c.	n.c.	n.c.
As	>10000	2420	1690	6830	7180	>10000	>10000	3240	>10000	>10000	>10000	>10000	>10000
Se	3.90	< 0.1	< 0.1	3.80	3.20	< 0.1	<0.5	0.10	0.30	1.20	1.60	3.30	1.70
Mo	1.22	1.09	1.16	1.27	1.65	1.18	1.10	2.59	1.00	1.00	2.00	0.60	0.60
Cd	>1000	26	72.3	>1000	950	5.45	6.60	102	167	195	26.9	417	185
In	1.87	0.58	4.42	114	91.1	0.25	n.c.	5.13	0.78	n.c.	n.c.	n.c.	n.c.
Sn	18.1	2.71	4.83	5.22	6.39	3.17	18.0	3.27	3.73	13.0	12.0	28.0	24.0
Sb	201	2.77	3.82	11.9	13.2	112	84.9	4.81	55.7	29.0	556	557	354
Te	0.03	<0.02	0.03	0.25	0.19	<0.02	n.c.	0.04	<0.02	n.c.	n.c.	n.c.	n.c.
W	0.1	0.2	0.2	0.1	0.2	0.2	1.7	0.3	0.2	1.5	1.1	<0.5	1.0
Tl	0.45	0.35	0.36	1.43	0.87	0.19	0.10	0.30	0.44	0.40	0.30	0.20	0.20
Pb	>5000	48.6	374	>5000	>5000	2090	2404	259	577	592	5586	3527	1086
Bi	1.31	1.25	12.2	160	63.0	1.51	1.40	7.91	0.90	0.80	82.5	24.2	22.9
Hg (ppb)	0.53	<10	0.08	2.38	1.76	0.03	0.04	0.13	0.22	0.24	0.16	3.52	1.49

Notes: n.c. = not collected, GM = Galena Mine, CS = Core Shack; [a] analysis by Pb fire assay; [b] analysis by Aqua Regia-MS; [1] Analyses completed at Activation Laboritories Ltd., Ancaster, Ontario, L9G 4V5; [2] Analyses completed at Bureau Veritas Commodities Canada Ltd., Vancouver, British Columbia, V6P 6E5.

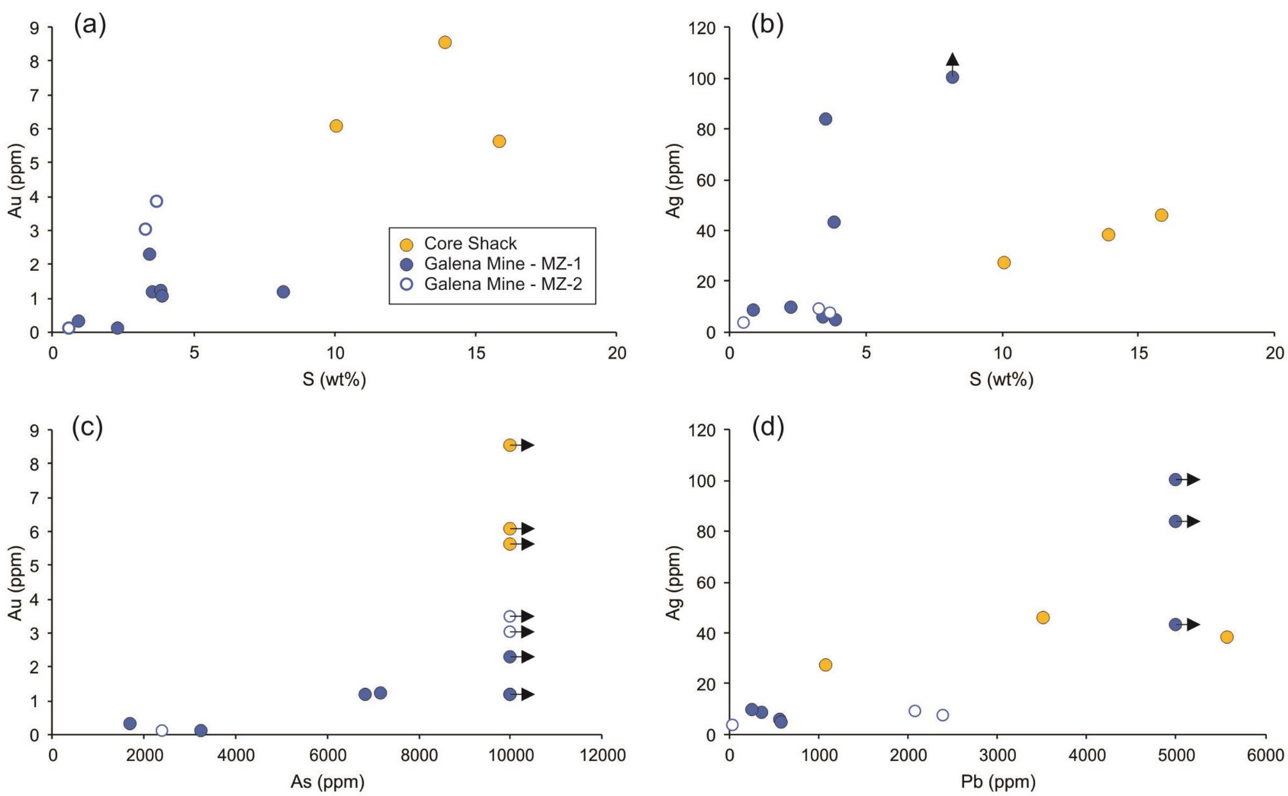

Figure 6. Plots of select precious and base metals in samples from the Core Shack and Galena Mine occurrences. Arrows in B, C, and D represent analyses above analytical confidence; therefore values plotted represent minimum concentrations. (a) Au (ppm) vs. S (weight per cent) content. (b) Ag (ppm) vs. S (weight per cent) content. (c) Au (ppm) vs. As (ppm). (d) Ag (ppm) vs. Pb (ppm).

mineralization at both Core Shack and Galena Mine occurred prior to deformation and metamorphism. The most abundant sulphide minerals recognized in the two occurrences are arsenopyrite, sphalerite, and galena, whereas chalcopyrite, pyrrhotite, and pyrite are found in lesser amounts. The presence of abundant arsenopyrite suggests that the original depositional environment of the Jumping Brook Metamorphic Suite may have been favourable for the deposition of gold. Petrographic and geochemical studies indicate that gold is hosted in arsenopyrite and silver in galena.

Acknowledgments

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