A Comparison of Analytical Methods Testing Soils for Gold Exploration in West Wales, Pembrokeshire

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1. Introduction

The Plumstone Mountain locality within Pembrokeshire has been an area of focus for prior exploration efforts by the British Geological Survey (BGS), revealing several prospective features through regional-scale geochemical and geophysical surveys. From July to October 2021, the author collaborated with Sarn Helen Gold to complete a soil sampling, rock chip sampling, and gold panning programme to follow up on these initial findings by the BGS. This synthesis of data analysis addresses a series of aims: (1) assess the prospective nature of the Plumstone Mountain study area; and (2) evaluate the effectiveness of pXRF, fire assay, multi-element, and ionic leach analytical techniques.

2. Background Geology

Plumstone mountain is located near the western part of the Treffgarne region, containing rocks that range from Precambrian to Ordovician in age (Figure 1). The focus of these is the Roch Rhyolite Group (Ordovician), a grouping of volcanic and sedimentary rocks. This group lacks significant exposure in the study area, likely due to extensive drift cover and has provided challenges in making mineralisation discoveries from outcrop (Cooper et al., 2000).

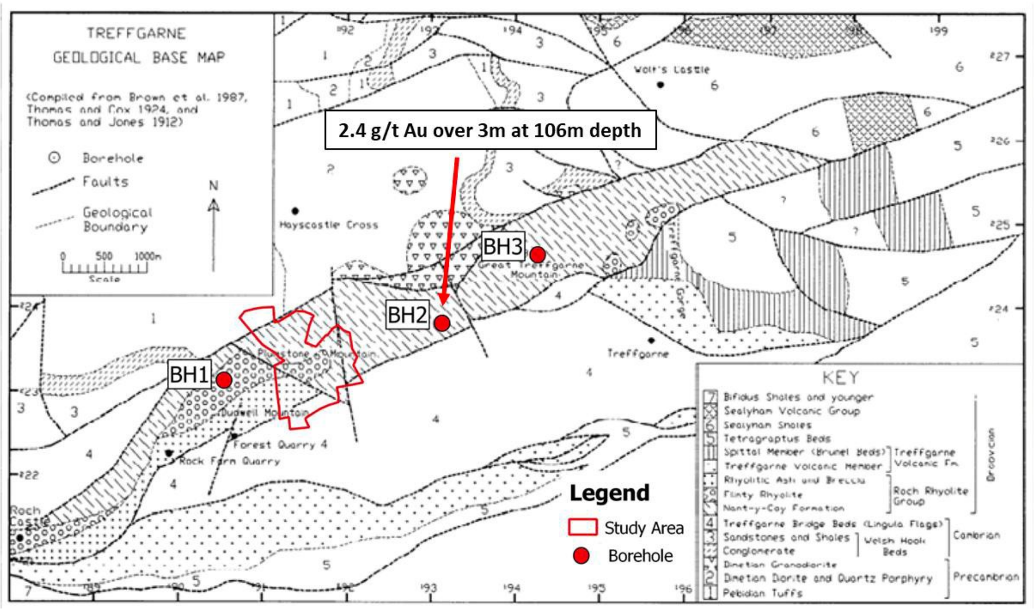

Figure 1: Annotated geological map of Treffgarne, with drillhole locations sited by the BGS. These boreholes helped identify the Roch Rhyolite Group as one of the most prospective mineral horizons for future exploration (modified from Brown et al., 1987).

Within the Roch Rhyolite Group is a succession of siliceous siltstones with thin muddy bands and volcaniclastic material known as the Nant-y-Coy Formation (Figure 2). This unit is frequently altered and contains abundant disseminated pyrite, being identified as a potential mineralisation horizon (Brown et al., 1987). The Roch Rhyolite Formation is also part of the Roch Rhyolite group and contains an intensely silicified 'Flinty Rhyolite', in addition to laharic breccias with abundant rhyolite blocks (Rhyolitic Ash and Breccia).

Age	Group/Formation			Lithology
Ordovician	Roch Rhyolite Group	Roch Rhyolite Formation	Rhyolitic Ash and Breccia	Laharic, silicified breccia composed of angular to subangular blocks of up to 1m long of rhyolitic rocks and mudstone in a muddy matrix and ash
			Flinty Rhyolite	Yellowish Grey, silicified rhyolite with blocky pseudo brecciated texture
		Nant-y-Coy Formation		Thinly laminated siliceous siltstones with muddy bands and volcaniclastic material. Frequently altered and contains abundant disseminated pyrite
Cambrian	Lingula Flags Formation			Green-grey micaceous shales with black, sandy mudstones
Precambrian	Unnamed Igneous Intrusion			Quartz-Feldspar porphyry
	Ramsey Sound Group			Andesitic tuff

Figure 2: Simplified lithological column of the geology at Plumstone Mountain (modified from Brown et al., 1987, Colman et al., 1995).

3. Responsible discovery

Land ownership was initially identified using the HM Land Registry and Sarn Helen Gold communication with private landowners (e.g. farmers) to gain permission for sample collection. Soil sampling was the primary method used to collect data as a cost-effective, non-invasive method of covering large target areas (Figure 3). A total of 294 samples being collected in the study area along north-south orientated lines, cutting across the major east-west structural trend.

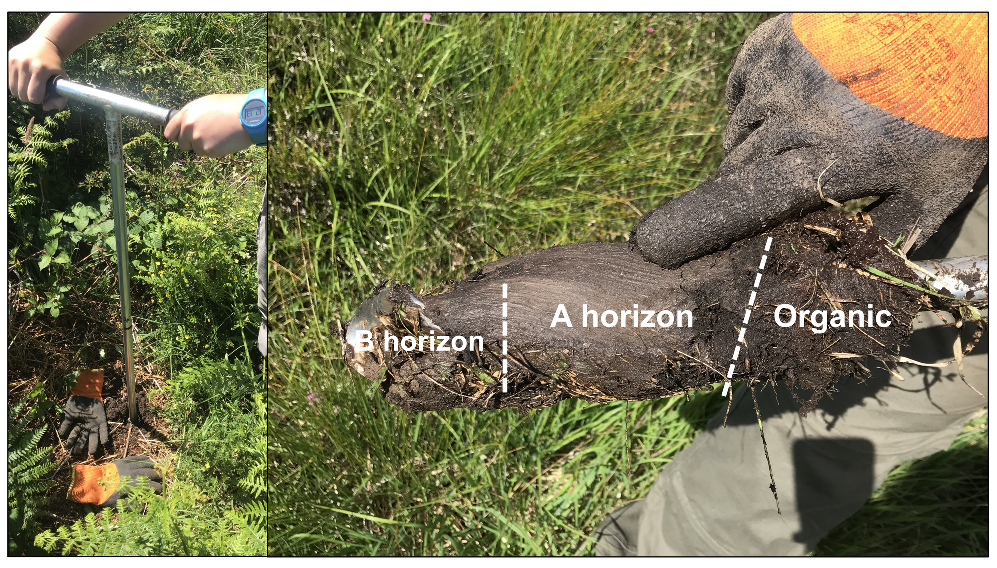

Figure 3: Auger being used in the field, with an annotated soil sample to highlight different soil horizons seen in the field.

4. Data Analysis

A detailed elemental suite of data was produced using a combination of pXRF, fire assay, multi-element analysis and ionic leach techniques. Data analysis was focused on identifying and mapping the concentration of typical Au pathfinders, which have a higher mobility than Au and may provide haloes around Au mineralisation. Although the initial focus was to use As as a pathfinder element (due to associations with arsenopyrite at Dolaucothi Gold Mines, Wales), this was expanded to other elements that correlate with Au to define vectors towards Au mineralisation. Statistical analysis has been used to determine which elements correlate strongly with Au (Table 1), and the spatial analysis has focused on establishing geochemical anomalies to guide mapping and exploration recommendations.

	Au (FA)	Au (IL)	As	Ba	Ca	Cu	Fe	Hg	Mn	Ni	Pb	Rb	Sm	Sr	Te	Ti	Zn
Au (FA)		-0.08	0.02	0.00	-0.03	**0.17**	0.13	0.00	-0.02	-0.09	-0.03	0.15	-0.09	-0.05	**0.20**	-0.02	**0.21**
Au (IL)	-0.08		0.21	-0.07	0.53	0.74	0.09	0.47	0.59	0.68	0.23	0.38	0.54	0.37	0.25	-0.03	0.22
As	0.02	0.21		0.29	-0.26	0.23	0.52	0.69	0.11	0.15	0.24	0.06	0.38	-0.09	0.59	0.60	0.25
Ba	0.00	-0.07	0.29		0.01	-0.08	0.05	0.30	0.03	0.17	-0.06	0.31	0.47	0.21	0.21	0.58	-0.09
Ca	-0.03	0.53	-0.26	0.01		0.45	-0.38	-0.07	0.43	0.63	0.13	0.34	0.39	0.80	-0.15	-0.40	0.13
Cu	**0.17**	0.74	0.23	-0.08	0.45		0.02	0.33	0.41	0.56	0.41	0.33	0.48	0.26	0.31	-0.04	0.35
Fe	0.13	0.09	0.52	0.05	-0.38	0.02		0.54	0.02	-0.17	-0.21	0.25	-0.12	-0.28	0.70	0.29	0.11
Hg	0.00	0.47	0.69	0.30	-0.07	0.33	0.54		0.21	0.26	0.12	0.27	0.37	-0.06	0.62	0.46	0.09
Mn	-0.02	0.59	0.11	0.03	0.43	0.41	0.02	0.21		0.81	0.15	0.58	0.56	0.49	0.18	-0.22	0.47
Ni	-0.09	0.68	0.15	0.17	0.63	0.56	-0.17	0.26	0.81		0.34	0.49	0.78	0.64	0.11	-0.09	0.38
Pb	-0.03	0.23	0.24	-0.06	0.13	0.41	-0.21	0.12	0.15	0.34		0.02	0.35	0.18	0.01	-0.08	0.41
Rb	0.15	0.38	0.06	0.31	0.34	0.33	0.25	0.27	0.58	0.49	0.02		0.32	0.39	0.38	-0.10	0.49
Sm	-0.09	0.54	0.38	0.47	0.39	0.48	-0.12	0.37	0.56	0.78	0.35	0.32		0.44	0.21	0.37	0.13
Sr	-0.05	0.37	-0.09	0.21	0.80	0.26	-0.28	-0.06	0.49	0.64	0.18	0.39	0.44		-0.12	-0.30	0.23
Te	**0.20**	0.25	0.59	0.21	-0.15	0.31	0.70	0.62	0.18	0.11	0.01	0.38	0.21	-0.12		0.43	0.29
Ti	-0.02	-0.03	0.60	0.58	-0.40	-0.04	0.29	0.46	-0.22	-0.09	-0.08	-0.10	0.37	-0.30	0.43		-0.16
Zn	**0.21**	0.22	0.25	-0.09	0.13	0.35	0.11	0.09	0.47	0.38	0.41	0.49	0.13	0.23	0.29	-0.16	

***Table 1:** Pearson's correlation matrix for selected ionic leach data (As-Ba-Ca-Cu-Fe-Hg-Mn-Ni-Pb-Rb-Sm-Sr-Te-Ti-Zn), including Au for fire assay (Au FA) and ionic leach (Au IL). Values greater than 0.55 have been classed as significant. Green = 0.55-0.60, Yellow = 0.61-0.70, Orange = 0.71-0.80, Red = 0.80+. Numbers in bolded red text highlight the highest correlations with Au that are below 0.55.*

Each lithology type present within the study area has distinct geochemical signatures, which have been used to refine lithological boundaries and produce an updated geological map (Figure 4). The pathfinder elements that have been prioritized include As, Cu, Fe, Mn, Pb and Zn, based upon significant correlations with Au and data from literature.

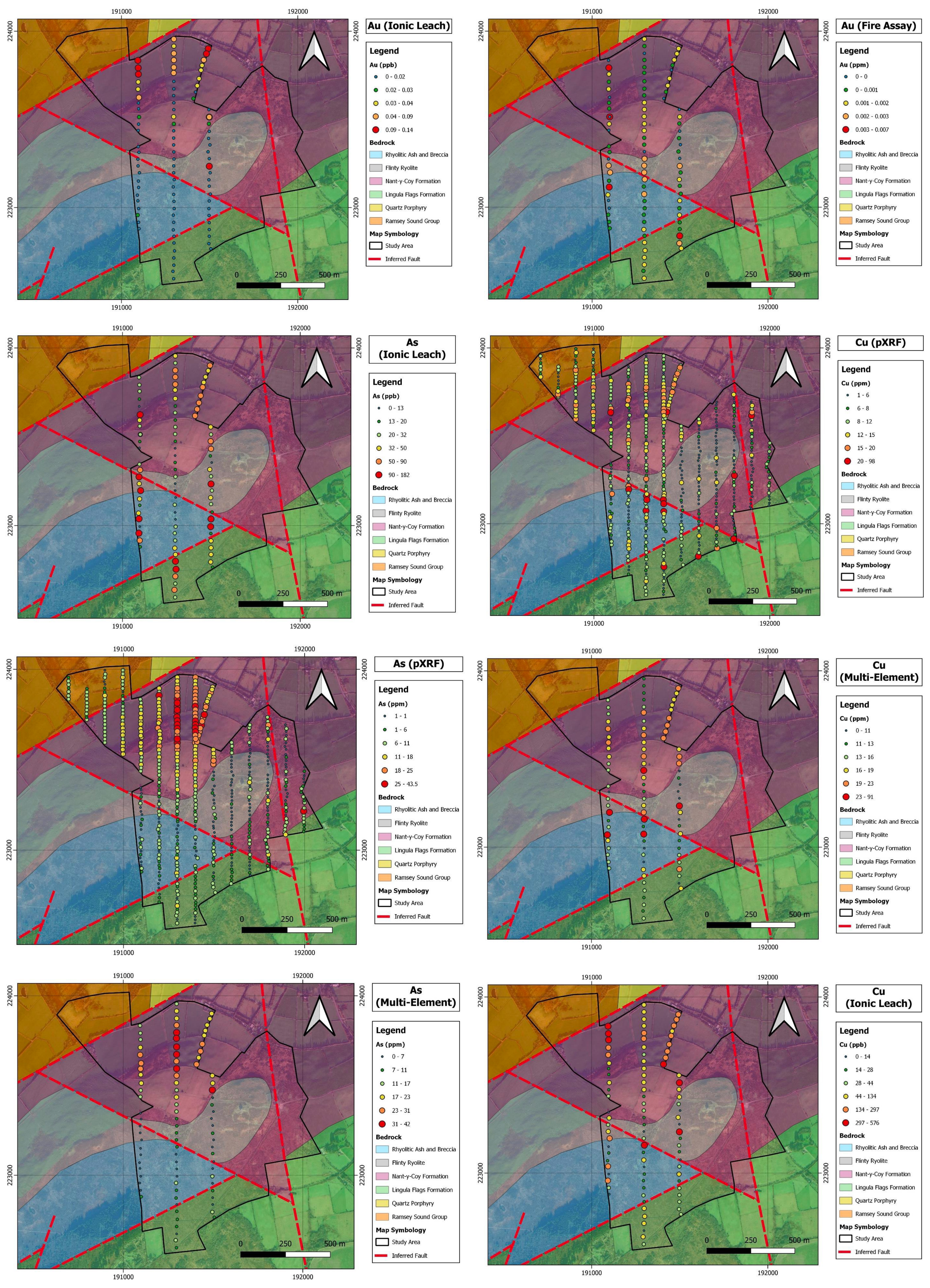

***Figure 4:** Au, As and Cu concentrations for soil samples analysed by pXRF, fire assay, multi-element analysis and ionic leach within the study area, identifying a northern spatial anomaly that corresponds with the Nant-y-Coy Formation.*

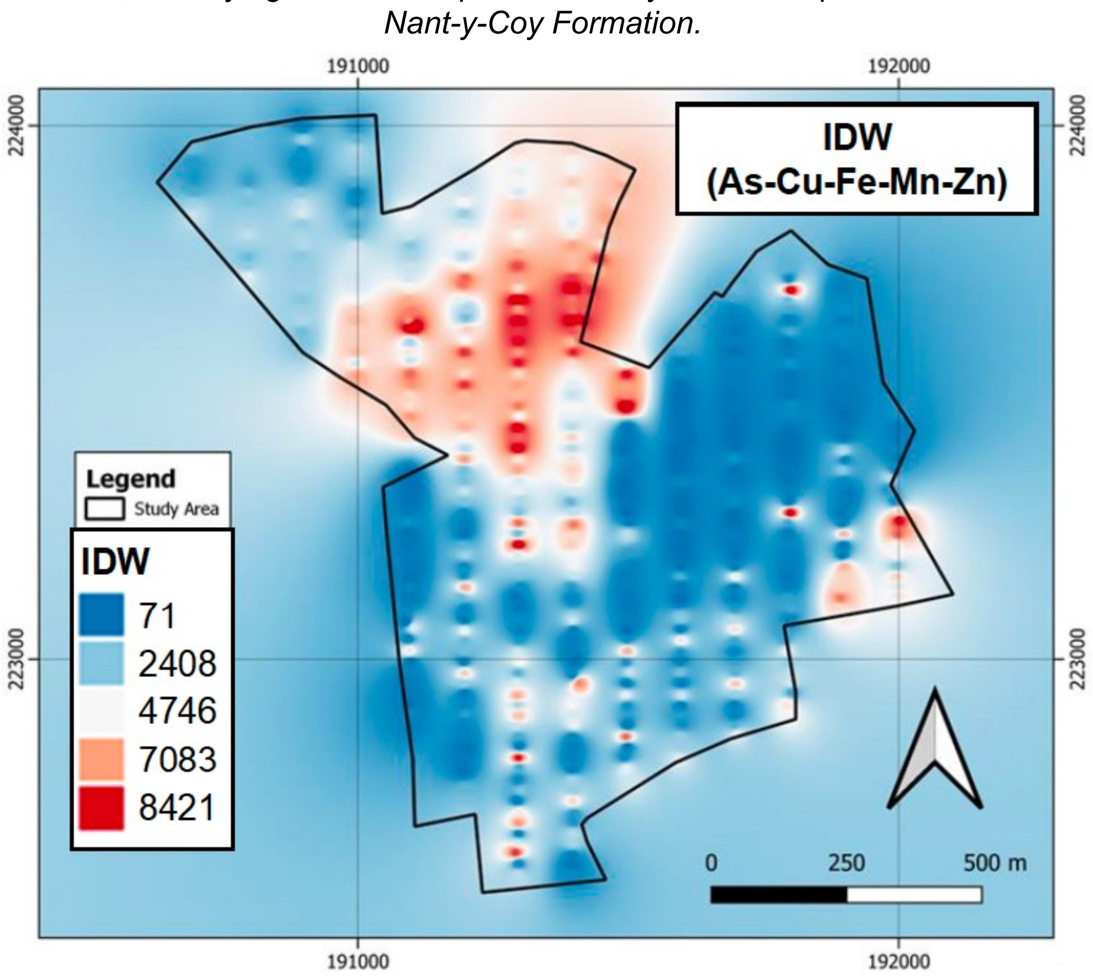

***Figure 5:** Inverse distance weighted interpolation of selected pathfinder elements (As-Cu-Fe-Mn-Zn), highlighting the extent of the northern geochemical anomaly. This enriched zone correspond with a high radiometric and chargeability anomaly to the north that was identified in historic BGS geophysical surveys.*

5. Discussion

The geology of Plumstone Mountain shares similar attributes to established VMS areas such as Parys Mountain (Anglesey), Avoca (Ireland) and the Bucans VMS district (Labrador). These deposits are all hosted in Ordovician aged host rocks, felsic-dominated submarine volcanic rocks and pyritic black shales present (Table 2).

Comparison of Plumstone Mountain to established VMS Areas				
Established VMS areas	Plumstone Mountain, Pembrokeshire	Parys Mountain, Anglesey	Avoca, Ireland	Buchans, Labrador
Geology				
Archean to Tertiary	Ordovician	Ordovician	Ordovician	Ordovician
Island arc / Greenstone	Back Arc	Back Arc	Continental Margin Arc	Island Arc
Bimodal basalt – Rhyolite submarine volcanics	Felsic – dominated submarine volcanic rocks	Felsic – dominated submarine volcanic rocks	Felsic – dominated submarine volcanic rocks	Mafic – Felsic dominated submarine volcanic rocks
Pyritic black shales present	Present (Nant-y-Coy Formation)	Present	Present	Present
Clusters of deposits	No known deposits	Several deposits	Several deposits	Several deposits
Ore Minerals				
Pyrite (common)	Abundantly disseminated (Roch Rhyolite Group)	Massive and disseminated	Massive and disseminated	Common
Chalcopyrite (common)	Not observed (sparse in Treffgarne)	Common	Common	Common
Galena (common)	Not observed	Common	Common	Common
Sphalerite (common)	Not observed	Common	Common	Common
Baryte (common)	Sporadic	Little reported	Little reported	Common
Hydrothermal Alteration				
Strong – loss of alkalis	Strong – loss of alkalis	Strong – loss of alkalis	Strong – loss of alkalis	Strong – loss of alkalis
Chloritisation (common)	Not observed	Intense Chloritisation	Intense Chloritisation	Intense Chloritisation
Silicification (common)	Intense silicification	Intense silicification	Intense silicification	Intense silicification

***Table 2:** Comparison between Plumstone Mountain and established VMS areas (modified from Colman et al., 1995).*

The signatures of the anomaly at Plumstone Mountain indicate that it would fall into the Zn-Pb-Cu group, with characteristically felsic and volcaniclastic host rocks, in addition to intense silicification and hydrothermal alteration characterised by loss of alkalis, with high Al and very low Na, K, Ca and Rb. Within VMS deposits, Au-rich massive sulphides are commonly associated with barite-rich assemblages that fit into the identified Bimodal-Felsic VMS type model (Figure 6).

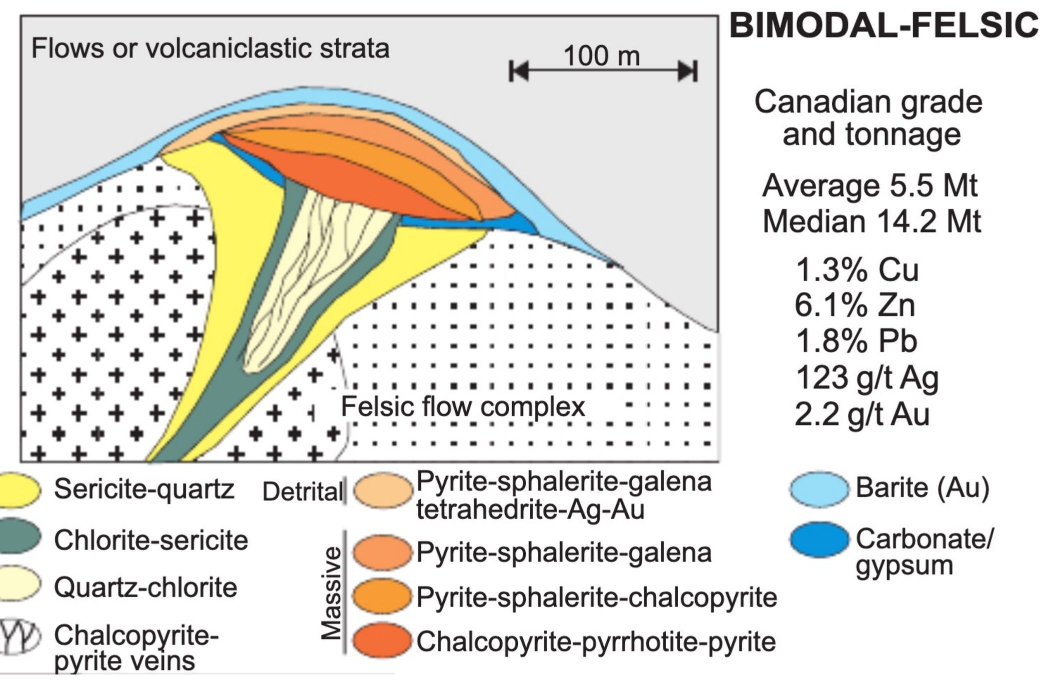

***Figure 6:** Proposed mineral deposit model based on the VMS lithological classifications from Barrie and Hannington (1999) and further modified by Franklin et al. (2005) (Galley et al., 2007).*

6. Conclusions

Regarding prospectivity, it can be concluded that there are geochemical anomalies suggesting potential indications for base-metal and precious-metal enrichment. A detailed elemental suite of data was produced using a combination of pXRF, fire assay, multi-element analysis and ionic leach techniques. The geochemical data gathered has been used to increase the resolution of the current BGS geological map. Most notably, the geological boundary of the most prospective unit for exploration, the Nant-y-Coy Formation, was able to be adjusted through using a combination of mapped element ratios along with Rb and Sr heat maps. If further work was pursued, the soil geochemical anomaly to the north should be investigated towards the north-east to understand its lateral extent via a combination of pXRF and ionic leach sampling.

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