Lithogeochemistry of the Spanish Mountain Gold Deposit, British Columbia (NTS 093A/11W)

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KEYWORDS: lithogeochemistry, alteration, Spanish Mountain, mineral deposits, Au, Carlin-type deposits, sediment-hosted disseminated Au deposits.

INTRODUCTION

The Spanish Mountain mineral property, located in the Cariboo region of central British Columbia is approximately 6 km east of the community of Likely in NTS map area 093A/11W (Figure 1). The deposit is hosted within a metasedimentary package of the Quesnel Terrane that occupies the hangingwall to the Eureka thrust, a structure that separates the Quesnel Terrane of the Intermontane Belt from the Kootenay Terrane of the Omineca Belt. The main geotectonic framework of the area includes the Cache Creek, Quesnel, Slide Mountain and Kootenay terranes (Figure 2). Skygold Ventures Ltd. currently owns 100% interest in the Spanish Mountain property and has been participating in the exploration of the property since 2003.

Sediment-hosted vein-type deposits along the Carlin trend in Nevada contain >200 million oz of Au (production+reserves+resources) and these deposits account for a large portion of production in the United States (Sillitoe, 2008). A similar style of Au deposits have also been discovered in China, Russia, Mexico, Southeast Asia and South America (Lefebure et al., 1999) and it has been suggested that accreted terranes such as Quesnel and Stikine, with basement carbonate rock types and associated intrusive events could host this type of sediment-related Au mineralization (Poulson, 1996). The Spanish Mountain property is described as an orogenic- or sediment-hosted Au deposit (Singh, 2008) based on the calcareous argillite hostrocks with microscopic Au, alteration style and tectonic setting. Spanish Mountain does not possess the same geochemical signature as sediment-hosted Au deposits described by Schroeter and Poulson (1996). To date, the only pathfinder element identified is Au.

FIELDWORK

Fieldwork was undertaken in June 2008, and consisted of a broad sampling of bedrock lithological units identified on the property by Skygold Ventures Ltd. (Singh, 2008). Skygold detected a negative correlation between Mg and Mn within Au-bearing rock types from an examination of their lithogeochemical data (Singh, 2008). Interest lies in inferring how the geochemistry of Au-bearing zones and barren rock differ from each other and from those of previous sediment-hosted Au deposits. With this in mind, 35 surface outcrop samples were obtained, targeting Mg-Fe carbonate-enriched samples often containing substantial

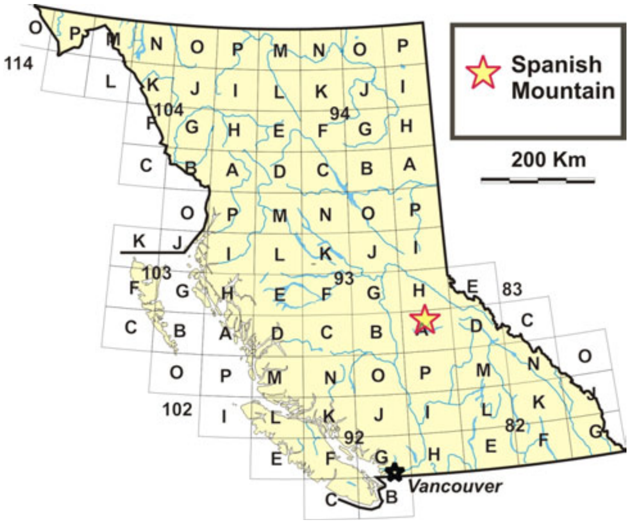

Figure 1. Location of the Spanish Mountain study area, central BC.

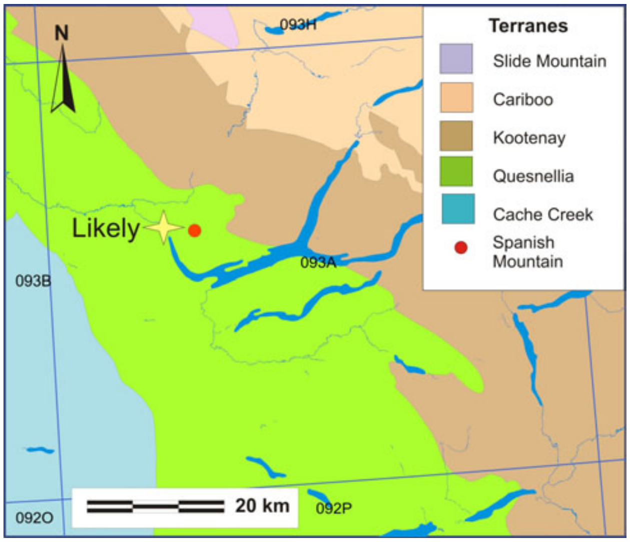

Figure 2. Geology of NTS map area 093A showing the relationship of host Quesnel Terrane to that of the Kootenay Terrane.

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sericite. The majority of samples collected were of the more competent wacke and siltstone units due to the emphasis on collecting unweathered samples to obtain suitable material for laser ablation inductively coupled–plasma mass spectrometry (ICP-MS) analysis. However, hostrocks for the majority of Au mineralization are phyllite and argillite, which are typically deeply weathered and oxidized. Skygold Ventures Ltd. generously donated 18 additional samples of diamond-drill core to supplement the surface outcrop samples. These samples provided examples of relatively unoxidized barren and ore-grade specimens. Figure 3 shows the location of samples taken for geochemical analysis and for preparation of thick and thin sections.

SAMPLE ANALYSIS

All rock samples were prepared for geochemical analysis at the BC Geological Survey (BCGS) Laboratory in Victoria, BC. Rock samples were first crushed to <2 mm using a jaw crusher fitted with hardened chromium-steel plates, then split into 100–200 g subsamples using a Jones splitter. Subsamples were taken from the <2 mm material for milling. A tungsten-carbide (W-C) ring and puck mill was used to mill one subsample of the jaw-crushed material for major oxide analysis, while a second subsample for minor- and trace-element analysis was prepared using a chrome-steel (Cr-Fe) ring and puck mill. A quartz sand was milled between each sample to minimize intersample contamination. Time and care were taken to choose fresh rock surfaces, but due to the extreme surface oxidization and extensive heterogeneity of veining within samples, milled portions may contain minor built-in bias of certain elements (e.g., SiO_2). Duplicate samples were inserted to monitor analytical precision, and known rock standards were added to measure accuracy.

A portion of each milled sample was analyzed for major oxides at Global Discovery Laboratories Ltd. (Vancouver, BC) on a fused disk with a Siemens Model SRS 3000 x-ray fluorescence spectrometer. Hafnium, niobium and zirconium (high field-strength elements) were also analyzed by x-ray fluorescence using a lithium metaborate-tetraborate pressed pellet and a Siemens SRS 3000 x-ray fluorescence spectrometer. Loss on ignition (LOI) was also determined at 1100°C by Global Discovery Laboratories. Other subsamples of the Cr-Fe milled material were analyzed for 42 trace elements at Acme Analytical Laboratories (Vancouver, BC) by hydrofluoric-perchloric-nitric-hydrochloric acid digestion followed by a combination of inductively coupled plasma–emission and mass spectrometry (ICP-ES and ICP-MS) as well as for 37 major and trace elements by a less rigorous aqua regia (HCl, HNO_3, H_2O) digestion followed by ICP-MS. The samples were also analyzed by Acme Analytical Laboratories for carbonate C by hydrochloric acid digestion and Leco combustion. A further set of subsamples was analyzed for 33 elements including Au and a selection of rare-earth elements by instrumental neutron activation analysis (INAA). Selected samples were analyzed for rare-earth elements at Memorial University (St. John’s, NL) by sodium peroxide sinter and ICP-MS. The advantage of using different nondestructive and extraction (total and partial) methods for analyzing elemental concentrations is that the data produced should aid in determining the most reliable analytical method for a given element or Group of elements in further research. Table 1 summarizes detection limits for elements analyzed by the different methods. Twenty-six selected rock specimens were sectioned at the BC Geological Survey and cut samples sent to Vancouver Petrographics (Langley, BC) for thin and thick section preparation.

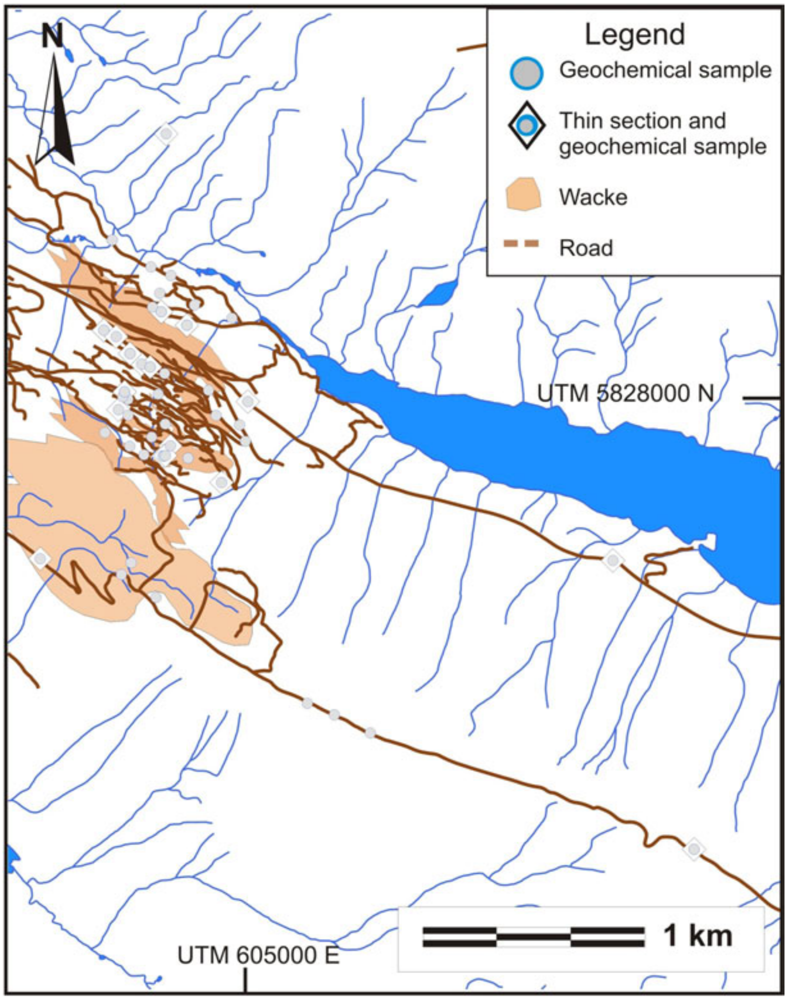

Figure 3. The Spanish Mountain property, with sample locations for petrographic and geochemical analysis highlighted. Wacke surface trace provided by Skygold Ventures Ltd.

GEOLOGY

Regional Geology

Gold mineralization at Spanish Mountain is hosted in metasedimentary rocks of the Late Triassic to Early Jurassic Nicola Group (Bloodgood, 1988) or its northern equivalent the Takla Group (Rees, 1987). In the eastern part of the property, these sedi-

Element	XRF	AR ICP-MS	HF ICP-MS	INAA	REE	Other
Units	ppm	ppm	ppm	ppm	ppm	%
Ag		0.002	0.1	5		
Al		200	100			
As		0.1	1	0.5		
Au		0.0002	0.1	0.002		
B		20				
Ba		0.5	1	50		
Bi		0.02	0.1			
Be			1			
Br				0.5		
Ca		200	100	10000		
Cd		0.01	0.1			
Ce			1	3	0.14	
Co		0.1	0.2	1		
Cr		0.5	1	5		
Cs				1		
Cu		0.01	0.1			
Dy					0.3	
Ho					0.06	
Er					0.24	
Eu				0.2	0.18	
Fe		200	100	100		
Ga		0.1			0.35	
Hf			0.1	1	0.39	
Hg		0.005		1		
Ho					0.06	
Ir				0.005		
K		200	100			
La		0.5	0.1	0.5	0.18	
Li			0.1			
Lu				0.05	0.09	
LOI						0.01
Mg		200	100			
Mn		1	1			
Mo			0.1	1		
Na		20	10	100		
Nb	3		0.1			
Nd				5	1.1	
Ni		0.1	0.1	20		
P		10	10			
Pb		0.01	0.1			
Pr					0.11	
Rb			0.1	15		
S		400	1000			
Sb		0.02	0.1	0.1		
Sc		0.1	1	0.1		
Se		0.1		3		
Sm				0.1	0.8	
Sn			0.1	200		
Sr		0.5	1	500		
Ta			0.1	0.5	0.42	
Tb				0.2	0.08	
Te		0.02				
Th		0.1	0.1	0.2	0.08	
Ti		10	1000			
Tl		0.02				
Tm					0.05	
U		0.1	0.1	0.5		
V		2	1			
W		0.1	0.1	1		
Y	3		0.1			
Yb				0.2	0.41	
Zn		0.1	1	50		
Zr	3		0.1			
CO_2						0.02

Table 1. Instrumental detection limits for elements determined by pressed pellet x-ray **fluorescence** (XRF), aqua regia digestion–ICP-MS (AR–ICP-MS), hydrofluoric-perchloric-hydrochloric-nitric acid digestion and combination of ICP-MS and ICP-ES (HF ICP-MS) and instrumental neutron activation analysis (INAA). Rare-earth element (REE) and carbonate carbon by LECO combustion. Detection limit for a major oxide (e.g., SiO_2, Al_2O_3) by fused-disc XRF is 0.01%.

Figure 4. Altered wacke displaying oxidized Mg-Fe-rich carbonate (right of image) and pervasive sericite alteration that resembles silica flooding (08KAP-02-04, UTM Zone 11, 604143 N, 5827859E, NAD 83).

Figure 5. Typical argillite with graphitic fracture surface showing rusty weathered pyrite, Fe-Mg carbonate and a displaced and distorted quartz vein (08KAP 04-07, UTM Zone 11, 604310N, 5828487E, NAD 83).

mentary rocks overlie the Middle Triassic black phyllite, which forms the basement Member of the Quesnel Terrane. The Middle–Late Triassic age constraint for the hostrocks in the study area comes from conodonts found in the vicinity of Quesnel Lake (Struik, 1983; Struik and Orchard, 1985). The Crooked amphibolite of the Late Paleozoic Slide Mountain Terrane (Schiarizza, 1989) separates the Quesnel Terrane to the west from the Kootenay Terrane in the east. Adjacent to the Spanish Mountain property, the Kootenay Terrane is composed of Paleozoic metasedimentary rocks of the Snowshoe Group and the Quesnel Lake orthogneiss. Southwest of Spanish Mountain, the sequence grades stratigraphically upwards into a sequence of volcanic wacke and associated volcanic rocks of the Nicola Group (Bloodgood, 1988).

Property Geology, Alteration and Mineralization

The host sedimentary rocks for Au mineralization and alteration are calcareous argillite, siltstone and wacke. Northern parts of the property are dominated by fissile black, thin-bedded argillite and siltstone with graphitic fracture surfaces. Quartz veins are present throughout argillite sequences with variable characteristics: containing pyrite, carbonate and rare galena; barren, highly deformed, or relatively undeformed and follow wavy bedding surfaces. The variation in quartz vein geometry and style demonstrate that fluid flow has been important throughout the deformational history. Surface outcrops of the main zone (Singh, 2008) are chiefly composed of wacke, siltstone and argillite sequences. The wacke is grey to buff white in colour with variable amounts of disseminated and well-formed cubic pyrite that is generally less than 5% of the rock. The siltstone is grey to black colour, occurring as thin beds and rounded boudins within phyllitic members. In the main zone, there is also wide variation in the character of the quartz veins hosted in the more competent wacke. It is of note that quartz veins within this unit have historically produced the highest Au assay values on the property (Singh, 2008). The siltstone and wacke have been intruded by minor mafic dikes, which are altered to a dark green colour and contain Cr-rich mica. Similar Cr-mica alteration occurs as subangular to angular fragments within the wacke sequence. Figures 4 and 5 show examples of the wacke and graphitic argillite.

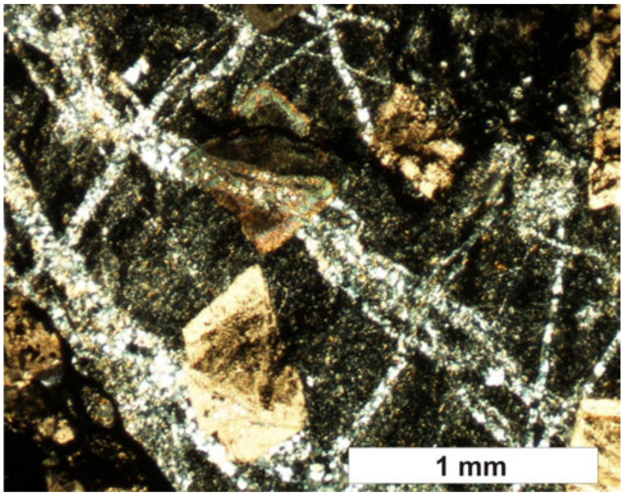

Figure 6. Thin section of siltstone displaying quartz veinlet interaction with rhombic carbonate. Interactions include termination, deflection and inclusion of quartz with or without carbonate remobilization (drillcore sample, UTM Zone 11, 604544 N, 5828363E, NAD 83).

Alteration on the property consists of extensive iron carbonate, dolomite and sericite replacement and oblitera-

Table 2. Summary of selected statistics for major and trace elements in Spanish Mountain rock samples. Abbreviations: ARMS, aqua regia digestion and ICP-MS; HFMS, hydrofluoric-perchloric-hydrochloric-nitric acid digestion and ICP-MS/ICP-ES; INAA, instrumental neutron activation analysis; CO_2 by HCl, digestion and LECO combustion; LOI, loss on ignition; XRF, x-ray fluorescence.

	Analytical Method	Units	Rock Type								
			Wacke Mean	Siltstone Mean	Argillite Mean	Wacke 95th %ile	Siltstone 95th %ile	Argillite 95th %ile	Wacke Max	Siltstone Max	Argillite Max
SiO_2	XRF	%	58.12	53.93	64.10	83.47	74.85	78.18	86.70	80.72	78.95
Al_2O_3	XRF	%	12.45	14.36	10.59	17.24	17.83	16.59	17.72	20.39	17.93
Fe_2O_3	XRF	%	5.03	6.21	4.79	8.07	9.30	8.52	8.19	11.43	8.84
MnO	XRF	%	0.13	0.14	0.19	0.22	0.21	0.58	0.25	0.24	0.77
MgO	XRF	%	3.56	3.33	2.54	11.79	6.09	5.78	12.17	6.11	7.14
CaO	XRF	%	4.66	4.83	3.52	6.85	8.06	7.54	6.88	8.76	7.82
Na_2O	XRF	%	2.18	2.62	1.07	4.08	5.18	2.08	4.73	6.61	2.11
LOI		%	10.34	10.48	9.12	21.55	16.05	16.97	22.43	17.46	17.34
Cu	HFMS	ppm	44.0	95.4	49.2	90.8	207.8	91.3	157.4	285.0	107.9
Pb	HFMS	ppm	6.7	9.5	25.1	12.5	28.1	91.9	21.5	35.8	153.7
Ni	HFMS	ppm	64.00	36.80	37.40	391.20	91.40	63.10	425.40	175.60	65.70
CO_2	LECO	%	7.67	7.88	5.47	16.55	12.89	11.77	16.70	14.28	13.22
Y	XRF	ppm	20	18	19	39	31	33	120	34	33
Zr	XRF	ppm	139	96	122	437	200	208	512	203	265
Nb	XRF	ppm	8	7	14	15	10	38	19	18	55
Au	INAA	ppb	118.6	329.4	33.9	420.9	1230.0	177.5	1820.0	5030.0	339.0
As	INAA	ppm	55.7	62.9	40.6	193.5	155.0	80.8	315.0	274.0	83.4
Ba	INAA	ppm	695	970	1029	1368	2000	2145	1470	2630	2410
La	INAA	ppm	12.3	16.2	17.9	24.8	26.0	32.9	25.4	48.4	41.1
Lu	INAA	ppm	0.33	0.41	0.42	0.56	0.64	0.70	0.59	0.71	0.73
Ag	ARMS	ppb	282.4	393.2	731.6	1333.8	782.0	3450.0	1678.0	1673.0	6623.0
S	ARMS	%	0.34	0.65	0.74	1.36	1.85	3.75	2.87	4.42	6.09
Hg	ARMS	ppb	4	3	18	12	8	77	26	8	137

tion of the majority of primary textures of all sedimentary units. Metamorphism has resulted in multiple stages of Fe-carbonate and/or high-Mg dolomite recrystallization that give the rocks a knotted appearance. Oxidation of Fe-bearing carbonate and pyrite has given the rocks a characteristic brown spotted appearance in many surface exposures. Muscovite alteration is also extensive throughout the property, occurring as fine-grained sericite, usually comprising between 20 and 40% of the matrix, but as high as 60% in some samples. Pyrite is observed as fine-grained disseminations throughout the wallrock, concentrated in veins and as euhedral cubes up to 2 cm. As many as three stages of pyrite growth have been identified by the University of Tasmania (Singh, 2008), but are nearly impossible to differentiate in hand sample.

PETROLOGY

Our petrographic analysis was designed to recognize possible mineralization vectors associated with carbonate mineralogy and to select samples for laser ablation ICP-MS at the University of Victoria. Mineral identification by microscopic examination of thin sections has been complemented by x-ray diffraction of 12 samples at Global Discovery Laboratories, Vancouver. The initial examination of the thin sections indicates that carbonate species occur in multiple generations; as irregular porphyroblasts with locally remobilized grain edges, well-formed zoned and unzoned prismatic rhombs, and patchy interlocking sections in intensely altered rock types. Figure 6 shows a thin section of an altered siltstone. Studying the different styles of carbonate replacement and observations of carbonate microchemistry will provide us with insight into the evolution of hydrothermal fluids responsible for wallrock alteration.

LITHOGEOCHEMISTRY—PRELIMINARY RESULTS

Results from whole-rock and trace-element geochemistry have been obtained and an analysis of the data is in progress. Preliminary results are listed in Table 2, together with rock types assigned in the field. Initial examination confirms previous studies of the mineralization: that Au-bearing samples have low values of As, Hg, Sb, Ba, Ag, Ba and Tl, elements identified by Schroeter and Poulson (1996) to be characteristic geochemical signatures of sediment-hosted Au deposits. This leads to the hypothesis that the chemistry of mineralization at Spanish Mountain differs from that of the better-studied Carlin-trend deposits. By obtaining and analyzing detailed geochemistry of the hostrocks, the intriguing potential exists in developing a new model explaining some of the unique characteristics of this sediment-hosted Au system. Refinement of hostrock types based on geographic and stratigraphic distribution will be part of ongoing undergraduate thesis work to better characterize alteration patterns of this deposit. Table 2 lists mean, 95th percentile and maximum values for selected major oxides, minor and trace elements, LOI and carbonate C for samples classified as wacke, siltstone and argillite. This tripartite classification scheme may be revised after more detailed petrographic analysis. The statistics in Table 2 reveal that wacke samples have higher SiO_2, MgO, Ni, carbonate C, Zn and As, whereas siltstone samples have higher Fe_2O_3, CaO, Cu and Au. Argillite samples have higher Pb, Nb, Ba, La, Ag, S and Hg.

CONCLUSIONS

Preliminary petrographic and geochemical analysis of surface outcrop and diamond-drill core samples from the Spanish Mountain property has revealed

- multiple generations of carbonate alteration minerals, including irregular porphyroblasts with locally remobilized grain edges, well-formed zoned and unzoned prismatic calcite rhombs, and patchy interlocking carbonate minerals in intensely altered rocks;
- principal rock types hosting Au mineralization at the Spanish Mountain deposit that display distinctive major oxide, minor- and trace-element chemistries; and
- a geochemical signature displayed by Spanish Mountain rock types that differs from previously discovered sediment-hosted Au deposits.

Further research into why elements such as As, Hg and Sb are in such low concentrations in the Spanish Mountain deposit leads to the exciting potential of a new deposit model for Au deposits in BC.

Among techniques that will be used to complete a study of alteration and lithogeochemistry are x-ray diffraction, rare-earth element analysis by sodium peroxide sinter–ICP-MS and laser ablation–ICP-MS analysis. Results and an analysis of the data will be reported in the senior author's University of Victoria Honours BSc thesis. It is anticipated that a detailed analysis of hostrock geochemistry and mineralogy will provide a better understanding of Au mineralization processes in the Spanish Mountain deposit.

ACKNOWLEDGMENTS

We would like to thank Jessica Doyle for her enthusiasm and assistance during fieldwork and throughout the summer. Permission from Scott Weeks, Skygold Ventures Ltd, to visit the Spanish Mountain property and collect samples is very much appreciated. Bob Singh is thanked for very generously spending time to advise on the geology and chemistry of the deposit and to suggest a practical focus for the study. We would also like to thank Roger MacDonald, Andrea Stevens and Bronwyn Azar of Skygold Ventures Ltd. for their expertise and hospitality during fieldwork. Gratitude is extended to Jim Logan for carefully editing a preliminary draft of this paper.

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