THE GEOCHEMISTRY OF MINERALIZED SKARNS IN BRITISH COLUMBIA

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KEYWORDS: economic geology, skarns, geochemistry, metal ratios.

INTRODUCTION

In this paper we present geochemical assay data for mineralized samples collected from over 60 skarns distributed throughout British Columbia (Figure 1). These samples were collected from all seven classes of calcic metallic skarn present in the province (Fe, Cu, Au, Mo, Pb-Zn, W and Sn) and represent both major producing deposits and smaller prospects (Table 1).

In addition to examining the varying metallic geochemistry (particularly the Au, Ag, Cu and Zn geochemistry) of the various skarn classes, we present some plots of metal element ratios that can assist prospectors and exploration geologists to geochemically differentiate gold, copper and iron skarns.

SAMPLES AND SAMPLE LOCATIONS

A total of 181 samples of mineralized skarn were collected for this study and a synopsis of the name and British Columbia MINFILE number of each sampled deposit or property is presented in Table 1. Each skarn class is represented by the following number of samples: iron skarns, 24; copper skarns, 84; gold skarns, 29; lead-zinc skarns, 10; tungsten skarns, 12; tin skarns, 10; molybdenum skarns, 12.

GEOCHEMICAL ASSAY RESULTS

Assay results for the 181 mineralized samples from the seven skarn classes are summarized in Table 2. It should be noted that all the samples were assayed for elements such as gold, silver, copper, lead, and zinc, but some samples were not analyzed for such elements as cesium, fluorine and mercury.

Some of the magnetite-rich iron skarn samples contain up to 10% sulphides, including chalcopyrite; this accounts for the unusually high average copper content (2.2%) of this skarn class compared to the copper skarns which average 3.3% copper. When the data for the magnetite-rich iron skarn samples are subdivided into sulphide-lean and sulphide-rich sets, it shows that the latter have a comparatively higher average content of gold, silver, copper, zinc, cobalt and arsenic (Table 3). The low gold and copper values in the sulphide-lean magnetite samples are more typical of iron skarn deposits in British Columbia.

Gold averages 20 ppm in the gold skarns, 8 ppm in the molybdenum skarns and 1.5 ppm in the copper skarns. The high average gold content of the molybdenum skarns is due to samples collected from the Novelty (82FSW107) and Giant (82FSW109) deposits at Rossland; these are unusual molybdenum skarns that contain anomalous gold, uranium, bismuth, cobalt, arsenic, nickel and tungsten (Fyles, 1984; Webster *et al.*, 1992; Ray and Webster, unpublished data).

The ore samples of tungsten skarn have the lowest gold content (<7 ppb) of all the skarn classes. Iron, tin and lead-zinc skarns are also low in gold although the more sulphide-rich magnetite iron skarn samples average 1206 ppb gold (Table 3).

Two of the three tin skarn prospects sampled, the Silver Diamond and Atlin Magnetite (MINFILE 104N 069 and 126) contain high amounts of silver (up to 459 ppm) which is reflected in the high average silver content of 85 ppm for this class. Lead-zinc and copper skarns also have high average silver contents (c. 70 ppm) whereas tungsten and molybdenum skarns have exceedingly low silver values (Table 2).

VARIABLE METALLIC ELEMENT CORRELATIONS IN THE SKARN CLASSES

The analytical results suggest that correlations between certain metals, particularly between gold, silver and copper, are highly variable in the different skarn classes. In iron skarns, there are good to excellent positive correlations between gold, silver and copper (Figure 2A, B and C). In copper skarns, copper and silver correlate positively with each other (Figure 3A), but neither of these two metals show a marked correlation with gold (Figure 3B and C). In gold skarns, however, there is no apparent correlation at all between gold, silver and copper (Figure 4 A, B, and C).

Although gold skarns are characterized by the highest average arsenic content of any skarn class (avg. 0.3% As) as well as very high bismuth abundances (Table 2), no significant correlation between gold and arsenic or between gold and bismuth is noted in this

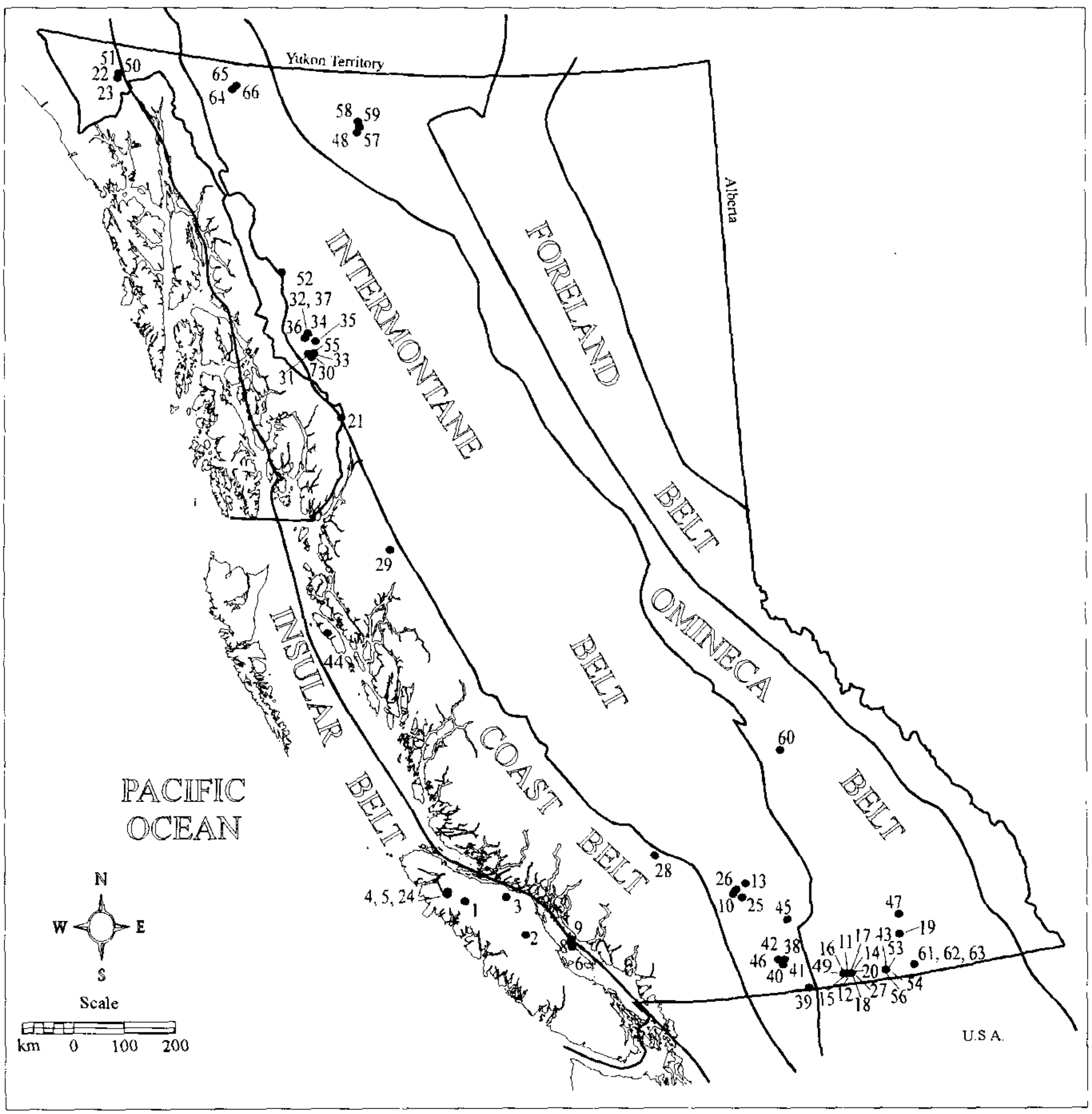


Figure 1. Location map of skarns sampled for this study. See Table 1 for property names.

Table 1. SKARN PROPERTIES IN BRITISH COLUMBIA SAMPLED FOR THIS STUDY.

	No. on Fig. 1	PROPERTY NAME	MINFILE No.		Map No.	PROPERTY NAME	MINFILE No.
Fe Skarns				**Au Skarns**			
	1	Iron Crown (Nimpkish Iron)	092L 034		38	Canty	092HSE064
	2	Iron Hill (Argonaut)	092F 075		39	Dividend-Lakeview	082ESW001
	3	Iron Mike	092K 043		40	French	092HSE059
	4	Kingfisher	092L 045		41	Good Hope	092HSE060
	5	Merry Widow	092L 044		42	Nickel Plate(Mascot)	092HSE036&38
	6	Prescott /Paxton /	092F 106/107		43	Jumbo	082FSW 111
		Yellow Kid / Lake	258/259		44	Banks, Discovery	103G 025
	7	Kirk Magnetite	104B 362		45	Oka	082ENW 025
Cu Skarns					46	Peggy	092HSE 066
	8	Little Billie	092F 105	**Pb-Zn Skarns**			
	9	Loyal	092F 265		47	Piedmont	082FNW129
	10	Craigmont	092ISE035		48	Contact	104P 004
	11	Emma	082ESE062		49	Cyclops	-
	12	Greyhound	082ESE050		50	Adams	114P 010
	13	Lucky Mike	092ISE027		51	Lawrence	114P 011
	14	Marshall	082ESE031		52	Devils Elbow	104G 012
	15	Morrison	082ESE052	**Mo Skarns**			
	16	Mother Lode /Sunset	082ESE034		53	Coxey	082FSW110
	17	Oro Denoro	082ESE063		54	Giant	082FSW109
	18	Phoenix	082ESE020		55	Josh	104B 290
	19	Queen Victoria	082FSW082		56	Novelty	082FSW 107
	20	Snowshoe	082ESE025				
	21	Molly B	103P 085	**W Skarns**	57	Dead Goat	104P 079
	22	Maid of Erin	114P 007		58	Lamb Mt	104P 003
	23	State of Montana	114P 008		59	Kuhn	104P 071
	24	Old Sport	092L 035		60	Dimac	082M 123
	25	Chase	092ISE 045		61	Dodger	082FSW011
	26	Eric	092ISE 036		62	Emerald Tungsten	082FSW010
	27	Brooklyn/Idaho	082ESE 013		63	Feeney	082FSW247
	28	Chalco 5	092JNE043	**Sn Skarns**			
	29	Lady Luck	103I 013		64	Silver Diamond	104N 069
	30	Cam 9	104B 326		65	Atlin Magnetite	104N 126
	31	Stu	104B 313		66	Daybreak	104N 134
	32	Dundee	103G 137				
	33	Shan	104B 023				
	34	Ken	104B 027				
	35	Tic	104B 367				
	36	Dirk	104B 114				
	37	McLymont	104B 281				

class (Figure 4D and E). However, cobalt does correlate positively with silver and arsenic in gold skarns (Figure 4F and G).

Nearly all of the scheelite-bearing tungsten skarn samples analyzed contain no, or very little, sulphide and the gold assays are so low that no meaningful correlations between gold and other metals could be observed. However, a number of interesting element associations were detected in tungsten skarns, including positive correlations between copper and cobalt, and thorium and cesium, and a negative correlation between cobalt and cesium (Figure 5 A, B and C). Positive correlations were also noted between cadmium and fluorine and between zinc and fluorine.

It should be noted that certain arsenopyrite-rich samples from the Emerald Tungsten camp do contain significant amounts of gold (Webster *et al.*, 1992). However, these were excluded from our set of tungsten skarn samples because they do not contain scheelite and it is not yet determined whether this economically interesting and distinctive mineralization is genetically related to the tungsten skarn system.

The molybdenum skarn samples can be subdivided into two sets: those from the Rossland deposits with high gold contents and the remainder that are generally low in gold. Plots using these sets indicate gold correlates positively with cobalt, selenium, tellurium, bismuth (Figure 6 A to D) as well as with antimony and arsenic. However, gold in these skarns correlates negatively with zinc and copper (Figure 6E and F) and molybdenum correlates negatively with zinc (Figure 6G).

Although gold in the tin skarn samples only average 127 ppb (Table 2), it shows a moderate positive correlation with bismuth, nickel and cobalt (Figure 7).

In lead-zinc skarns, no correlation between the low quantities of gold present (averaging 20 ppb) and any other metal was detected. However, positive correlations between silver and antimony (probably due to the presence of tetrahedrite), and silver and lead were noted, as well as negative correlations between zinc and copper, and between arsenic and bismuth (Figure 8).

USING METAL RATIOS TO DIFFERENTIATE SKARN CLASSES

Previous studies (Ettlinger and Ray, 1989; Ray *et al.*, 1990; Myers and Meinert, 1990; Theodore *et al.*, 1991) have attempted to use metal ratios, notably gold/copper and gold/silver ratios, to characterize or distinguish between gold, copper and iron skarns. Einaudi (personal communication 1993) has also recognized that plots of gold (in ppm) versus silver/gold ratios can differentiate between some porphyry copper deposits and their related satellite copper skarns.

Table 2. SUMMARY OF ASSAY RESULTS OF MINERALIZED SKARN SAMPLES

	Fe Skarns					Cu Skarns				
	Average	Max	Min	Stdev	n	Average	Max	Min	Stdev	n
Au-ppb	530	4500	1	1010	24	1503	29100	2	4040	84
Au-ppm	0.530	4.5	0.001	1	24	1.503	29.100	0.002	4.040	84
Ag	25	195	0.001	51	24	78	1800	0.4	292	86
Cu	22050	133000	11	41857	24	33506	350800	33	66551	86
Pb	10	50	2	13	24	53	715	2	108	86
Zn	537	3511	30	977	24	8601	210000	15	36113	86
Co	371	2700	11	640	24	190	4860	2	560	86
Ni	51	446	1	120	13	53	660	1	91	73
Mo	44	900	1	184	24	84	2100	1	316	86
As	4624	107000	6	21810	24	349	9600	1	1307	86
Sb	3	11	1	3	11	5	78	1	10	78
Bi	5.9	32.0	1.5	6.3	21	318.0	8200.0	2.0	1292.0	82
Cd	19.0	37.8	0.2	27.0	2	25.0	1000.0	0.1	140.0	51
Te	0.9	4.8	0.1	1.4	11	3.0	29.0	0.1	5.9	74
Se	2	12	0.1	4	11	18	210	0.1	34	74
Ba	158	1561	10	466	11	172	3000	10	467	66
Cr	24	73	8	25	6	90	290	19	55	44
Rb	-	-	-	-	0	18.5	68.0	2.5	15.0	39
W	1	1	1	0	2	293	5800	1	969	43
Ce	-	-	-	-	0	12.3	100.0	1.5	20.8	39
Th	-	-	-	-	0	1.2	12.0	0.1	2.4	38
F	-				0	1384	40300	40	6403	39
Sr	108	673	5	199	11	497	8654	5	1977	20
Hg	73	285	10	81	11	185	2100	20	444	27
Ag/Au	433	8474	4	1716		1089	40000	0.1	4843	
Cu/Au	214426	4347826	969	881180		879248	26000000	4	3469249	
Cu/Ag	799	2100	21	566		2635	55500	10	8264	
Zn/Au	13264	152652	35	32686		359364	9904762	3	1646520	
Zn/Pb	123	1756	1	353		495	31600	0	3433	

	Au Skarns					Pb-Zn Skarns				
	Average	Max	Min	Stdev	n	Average	Max	Min	Stdev	n
Au-ppb	19931	103000	137	28280	29	20	119	3	36	10
Au-ppm	20	103	0.137	28	29	0.020	0.119	0.003	0.036	10
Ag	29	715	1	132	29	71	159	2	59	10
Cu	2421	11800	4	3539	29	1964	8700	24	3051	10
Pb	71	1500	2	277	29	16524	46900	16	18235	10
Zn	134	730	12	139	29	112960	385000	12700	109671	10
Co	1039	17000	4	3266	29	67	290	3	89	10
Ni	168	850	16	206	14	131	610	1	212	8
Mo	30	300	2	67	24	24	105	2	36	10
As	34541	445000	13	98534	29	66	250	1	98	10
Sb	17	168	1	38	19	194	1100	1	365	10
Bi	1514.0	32000.0	2.0	6062.0	28	52.3	350.0	5.0	106.7	10
Cd	1.0	2.0	-	1.0	5	1519.0	4900.0	150.0	1477.0	10
Te	3.0	7.0	1.0	2.0	10	0.7	2.0	0.1	0.6	10
Se	17	58	1	19	10	11	35	1	12	10
Ba	727	1300	50	562	7	656	1500	61	618	8
Cr	81	100	69	11	7	52	97	17	28	8
Rb	47.0	110.0	9.0	49.0	7	46.9	100.0	36.0	35.0	8
W	125	320	1	169	5	8	24	1	8	8
Ce	19.4	50.0	5.0	17.8	5	7.6	24.0	9.0	8.0	8
Th	6.0	17.0	1.0	8.0	7	1.2	5.0	0.2	1.6	8
F	332	460	160	141	5	291	640	120	156	8
Sr	582	720	444	159	5	-	-	-	-	0
Hg	172	380	10	140	6	-	-	-	-	0
Ag/Au	7	170	0	33		14909	41333	54	14699	
Cu/Au	1065	44643	0	8424		430853	2175000	202	728947	
Cu/Ag	766	3933	1	997		90	368	1	134	
Zn/Au	57	766	0	143		15607973	43333333	756098	15388104	
Zn/Pb	14	56	0	14		258	1938	1	602	

	W Skarns					Mo Skarns				
	Average	Max	Min	Stdev	n	Average	Max	Min	Stdev	n
Au-ppb	5.3	7	5	1	12	8457	47200	35	14153	12
Au-ppm	0.005	0.007	0.001	0.005	12	8	47	0.035	14	12
Ag	0.8	2	0.4	0.4	12	6	25	1	7	12
Cu	406.9	2700	32	744	12	1082	3500	9	1237	12
Pb	49.5	441	8	123	12	23	57	7	15	12
Zn	8421.0	97000	66	27899	12	81	266	6	75	12
Co	46.4	192	8	66	12	5828	48400	4	13898	12
Ni	34.4	193	2	57	12	1712	12700	2	3855	12
Mo	233.3	1800	2	514	12	5151	31800	2	9271	12
As	1.8	4	1	1	12	54586	305000	4	93364	12
Sb	1.4	4	1	1	12	22	103	1	32	12
Bi	10.6	40.0	8.0	13.4	12	1009.8	3800.0	5.0	1378.0	12
Cd	25.9	300.0	0.1	86.3	12	0.5	1.0	0.3	0.3	12
Te	0.2	0.6	0.1	0.2	12	18.1	52.0	0.3	21.7	12
Se	1.3	5	1	1	12	24	100	5	27	12
Ba	170.3	340	93	113	12	1146	2600	10	845	12
Cr	97.0	390	43	96	12	81	120	41	26	12
Rb	130.3	530.0	35.0	176.0	12	151.0	240.0	24.0	84.0	12
W	14567.1	70000	35	26243	12	2965	23000	5	7174	12
Ce	63.5	420.0	4.0	118.0	12	68.7	190.0	26.0	52.0	12
Th	24.8	150.0	0.2	42.4	12	3.7	11.0	0.1	4.0	12
F	4722.1	30490	300	8516	12	418	560	200	100	12
Sr	252.0	491	13	338	2	-	-	-	-	0
Hg	-	-	-	-	0	20	20	20	0	2
Ag/Au	148.6	320	57	88		30	127	0	38	
Cu/Au	80154.8	540000	5571	149155		8395	24823	0	10161	
Cu/Ag	485.5	2700	64	744		325	1080	3	396	
Zn/Au	1682685.8	19400000	13200	5580336		844	4836	0	1397	
Zn/Pb	524.9	6063	1	1744		7	38	0	12	

	Sn Skarns				
	Average	Max	Min	Stdev	n
Au-ppb	127	646	5	202	10
Au-ppm	0.127	0.646	0.005	0	10
Ag	85	459	0	142	10
Cu	4092	10200	4	3939	10
Pb	1276	10400	10	3232	10
Zn	19476	165000	369	51501	10
Co	26	81	5	29	10
Ni	20	61	3	19	10
Mo	6	21	2	7	10
As	65	210	1	65	10
Sb	10	23	1	9	10
Bi	439.0	2400.0	32.0	737.0	10
Cd	348.4	2900.0	0.1	905.3	10
Te	9.7	81.0	0.1	25.2	10
Se	3	13	1	4	10
Ba	99	330	110	95	10
Cr	65	150	24	46	10
Rb	99.4	350.0	35.0	133.5	10
W	2007	5500	2	2190	10
Ce	4.1	14.0	5.0	4.1	10
Th	1.2	4.0	0.2	1.5	10
F	31422	59500	160	26823	10
Sr	36	107	5	33	8
Hg	-	-	-	-	0
Ag/Au	1988	8345	8	3090	
Cu/Au	88078	280000	122	111682	
Cu/Ag	65	175	4	57	
Zn/Au	767199	6600000	1767	2057936	
Zn/Pb	38	138	0	41	

n = number of samples assayed.

Analytical methods:
Geochemical laboratory, Ministry of Energy, Mines and Petroleum Resources, Victoria, B.C.
Au by fire assay and AAS finish;
Ag, As, Bi, Cd, Co, Cu, Ni, Mo, Pb, Sb and Zn by flame AAS,
Se and Te by hydride/AAS;
Ce and W by neutron activation at Activation Labs. Ltd., Ancaster, Ontario.

Table 3: COMPARISON BETWEEN SULPHIDE-LEAN AND SULPHIDE-RICH MAGNETITE (Fe SKARN) SAMPLES.

	Sulphide-lean	Sulphide-rich
No. of samples	11	13
Au	0.047	1.206
Ag	1.8	59
Cu	1101	51380
Pb	5	17
Zn	109	1136
Co	122	720
Ni	55	30
Mo	75	2
As	58	11016
Sb	3	3
Bi	5	7
Cd	0.2	38
Te	1.0	0.1
Se	2	2
Ba	172	10
Cr	29	13
W	1	1
Sr	55	248
Hg	70	95
Ag/Au	112	883
Cu/Au	31118	471057
Cu/Ag	624	1043
Zn/Au	11258	16072
Zn/Pb	34	248

Element data are average assay values in ppm.

samples have been used to calculate metal ratios. However, in this study we have used the assay data summarized in Table 2. Metal production statistics of mined-out skarn deposits can undoubtedly be valuable in defining some types of gold-bearing skarns (Orris *et al.*, 1987; Theodore *et al.*, 1991). However, using production statistics has several disadvantages: it limits the database to the larger deposits, historic recovery of certain metals may have been erratic due to changing economic factors and, because only the economic metals are extracted from a deposit during mining, plots are limited to a small number of metallic elements.

Plots based on assays of mineralized skarn samples may have problems due to sampling inhomogeneity, but a larger number of metallic elements can be tested in any metal ratio study. Another major advantage is that the plots can include samples from both large economic deposits and small skarn occurrences.

METAL RATIO PLOTS

A variety of metallic element ratio plots were constructed using the analytical data for gold, silver, copper, zinc, cobalt, arsenic and bismuth, summarized in Table 2. This exercise was undertaken to see whether it is possible to distinguish differences in metal element ratios in six of the seven skarn classes (due to the wide variation in gold content molybdenum skarns were not plotted).

Plots in which many of the skarn classes were successfully characterized are presented in Figure 9A to D. Copper/gold versus zinc/gold appears to be the best plot as it separates the sample points into four clusters (Figure 9A). The most distinctive cluster represents gold skarns which are characterized by the lowest copper/gold and zinc/gold ratios of all the six skarn classes. A second, marked by the highest zinc/gold ratios, is represented by lead-zinc skarns. Intermediate between gold and lead-zinc skarns are two more overlapping clusters represented by copper and iron skarns on the one hand, and tungsten and tin skarns on the other.

Plots of copper/gold versus silver/gold, copper/silver versus copper/gold and gold (in ppm) versus copper/gold are shown in Figure 9B, C and D; the first plot is similar to that used by Ettlinger and Ray (1989) and Ray *et al.* (1990). In all these three metal ratio plots, the majority of the gold skarn samples are readily distinguishable from those of the other skarn classes.

DISCUSSION

Current world mineral economics suggest that skarns containing gold±copper are the most economically attractive skarn targets for exploration. The assay data presented in this paper indicates that economically significant quantities of gold are not only to be found in gold skarns and some copper skarns but also, rarely, in some molybdenum skarns, such as those in the Rossland district. In addition, but to a much lesser degree, gold occurs in some calcic iron skarns although, as it is probably contained in chalcopyrite, economic gold ore is only likely to occur in sulphide-rich parts of the magnetite skarn.

In the field, it is often difficult to decide whether a newly discovered outcrop of skarn represents a gold, copper, iron or other class of skarn, particularly where the rocks are poorly exposed and only weakly mineralized. The opaque minerals in weakly mineralized outcrops may not necessarily be diagnostic because chalcopyrite, pyrite, pyrrhotite, magnetite and, to a lesser extent, sphalerite are among the most widely reported opaque minerals present in all classes of skarn throughout British Columbia.

This study suggests that assay data may help to differentiate gold, copper and iron skarns because the correlation between certain metals, particularly between gold, silver and copper, is markedly different in these three skarn classes. However, these different geochemical patterns indicate that particular care should be taken when sampling and testing skarn for gold. Prospectors and exploration geologists are

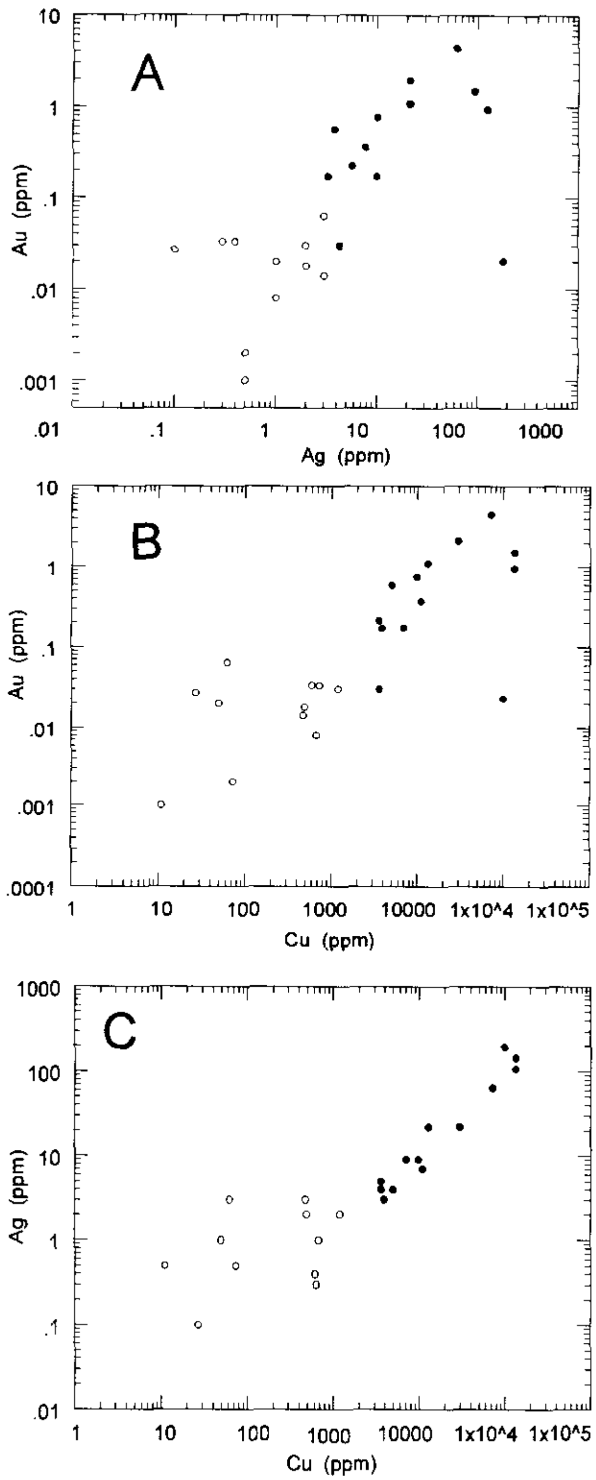


Figure 2. Plots for iron (magnetite) skarn samples (open circles = sulphide-lean; closed circles = sulphide-rich samples). A: Gold *versus* silver. B: Gold *versus* copper. C: Silver *versus* copper.

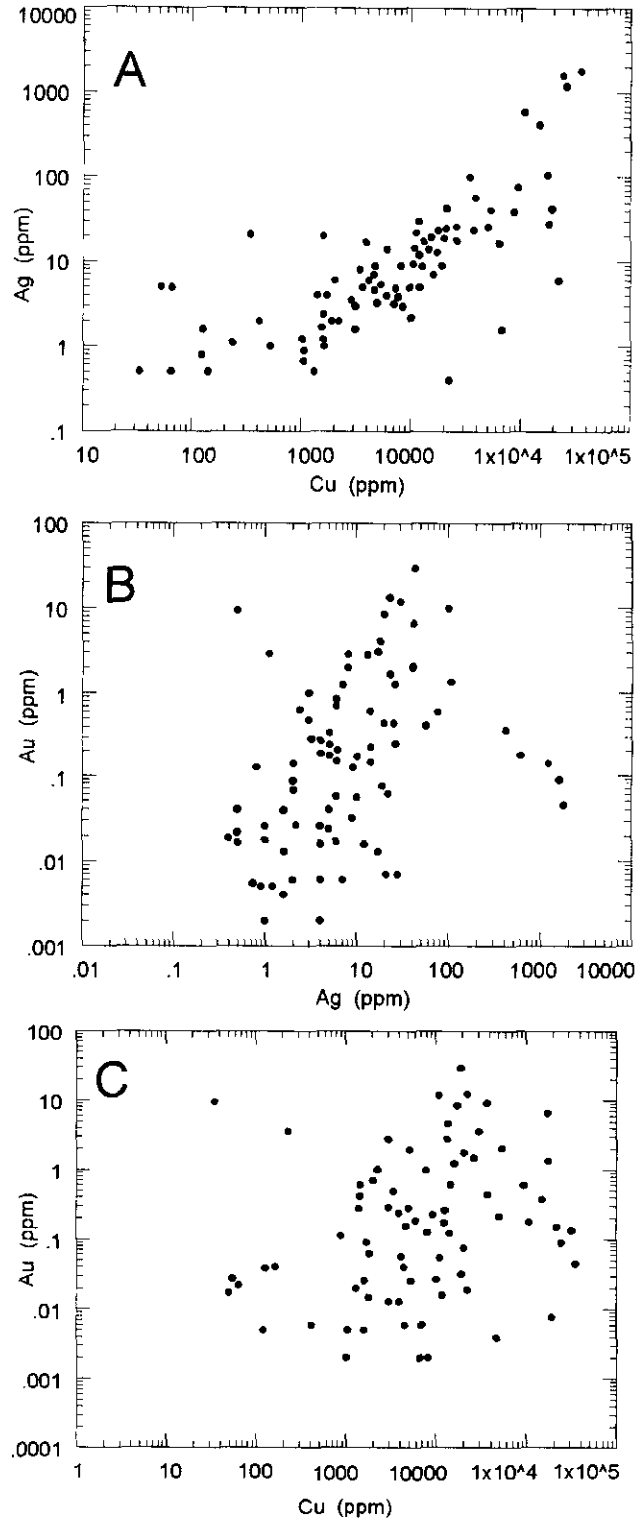


Figure 3. Plots for copper skarns. A: Silver *versus* copper. B: Gold *versus* silver. C: Gold *versus* copper.

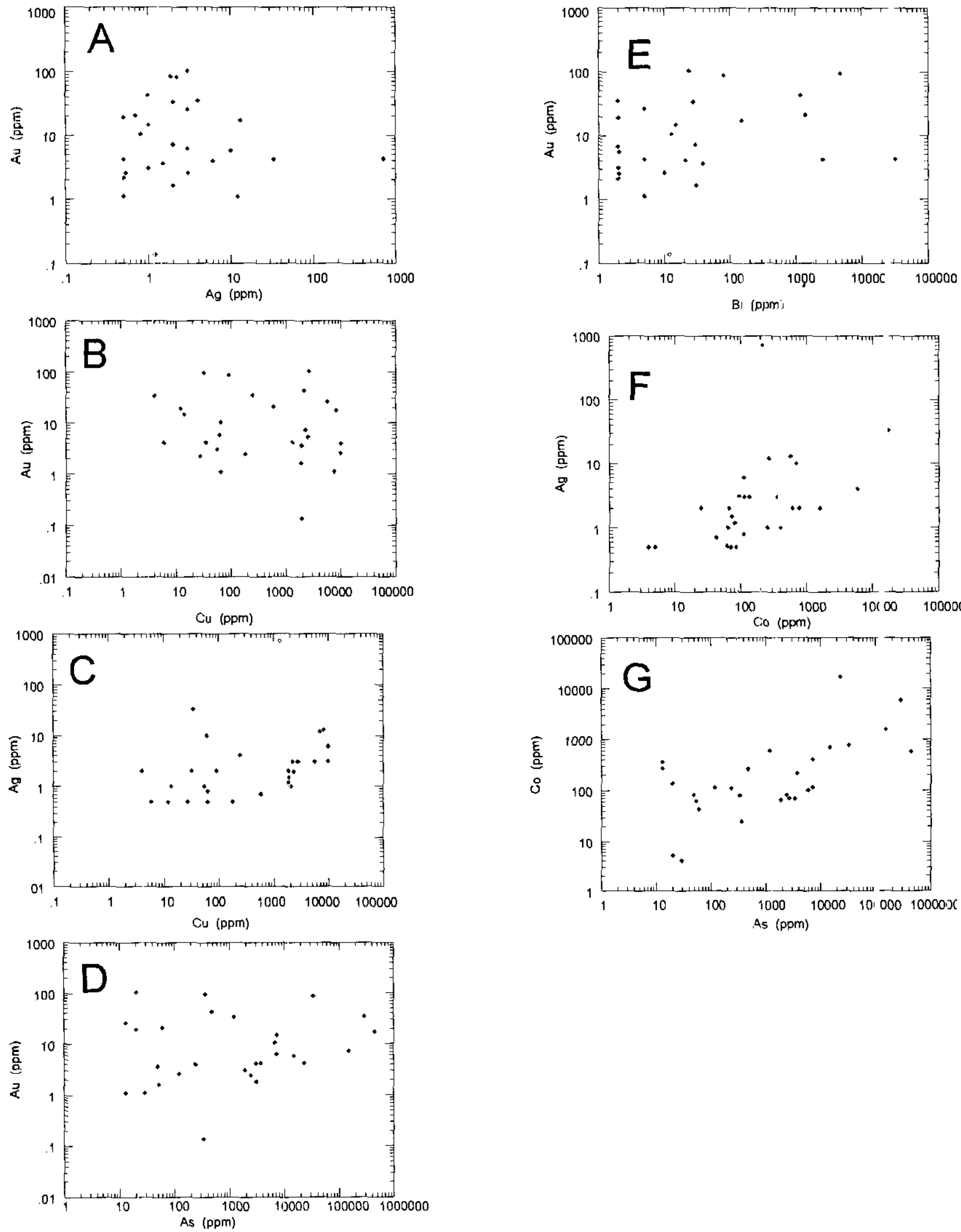


Figure 4. Plots for gold skarns. A: Gold *versus* silver. B: Gold *versus* copper. C: Silver *versus* copper. D: Gold *versus* arsenic. E: Gold *versus* bismuth. F: Silver *versus* cobalt. G: Cobalt *versus* arsenic.

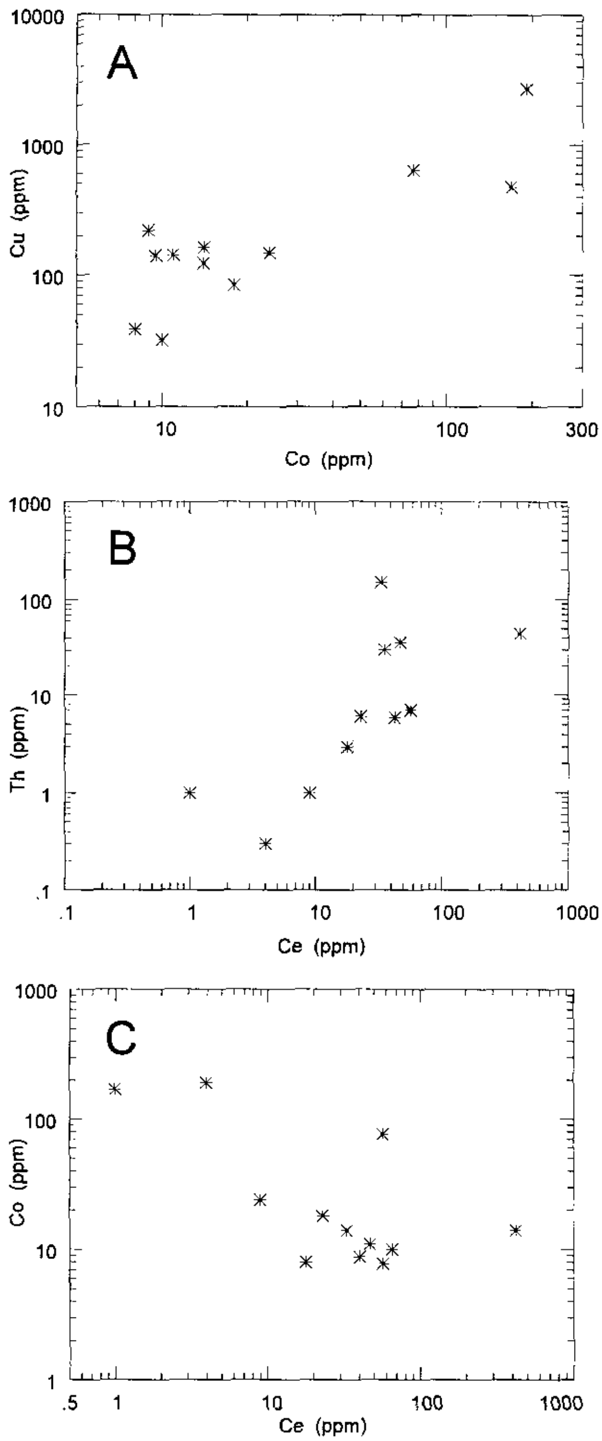


Figure 5. Plots for tungsten skarns (samples are scheelite rich and generally sulphide poor). A: Copper *versus* cobalt. B: Thorium *versus* cesium. C: Cobalt *versus* Cesium.

inclined to sample copper and/or sulphide-rich portions of a skarn prospect in the erroneous belief that these samples are most likely to contain gold. However, the absence of correlation between gold and copper in gold skarns and some copper skarns indicates that the gold potential of a skarn can easily be overlooked if copper-rich outcrops are preferentially sampled.

Although bismuth tellurides are a characteristic feature of many gold skarns (Ettlinger and Ray, 1989; Meinert, 1989; Ray *et al.*, 1990) and some gold-rich copper skarns, this study suggests that assaying for bismuth or tellurium is not reliable for detecting skarns with gold potential. This is probably because the bismuth tellurides are too erratically distributed in the skarn system to be reliably detected by analyzing grab samples.

CONCLUSIONS

- Significant amounts of gold occur not only in gold skarns, but in some copper, molybdenum and iron skarns in British Columbia. Rarely, gold-rich and scheelite-poor mineralization is also found in the some tungsten skarns, but it is uncertain whether this is genetically related to the skarn system.

- The correlation between gold and other metals such as silver, copper, zinc, arsenic, cobalt and bismuth is highly variable in the different skarn classes. For example, gold exhibits a good positive correlation with copper and silver in iron skarns but shows no association with these metals in gold skarns. These different patterns can be used to distinguish between mineralized outcrops of iron, copper and gold skarns.

- The lack of any clear association between gold and copper in gold skarns and some copper skarns indicates that the gold potential of a skarn will be overlooked if only skarn outcrops rich in copper sulphides are sampled. To successfully test a skarn for gold, all the different mineral assemblages should be sampled and assayed, including the sulphide-poor outcrops.

- This study suggests that plots of metal element ratios using analytical data obtained from mineralized grab samples can be used to differentiate some skarn classes, particularly gold, copper-iron and lead-zinc skarns. The most useful plot is copper/gold *versus* zinc/gold because gold skarns are distinguished from other skarn classes by having exceedingly low zinc/gold (<100) and copper/gold (<2000) ratios. Other useful plots include copper/gold *versus* copper/silver, copper/gold *versus* silver/gold, and gold (in ppm) *versus* either copper/gold or silver/gold.

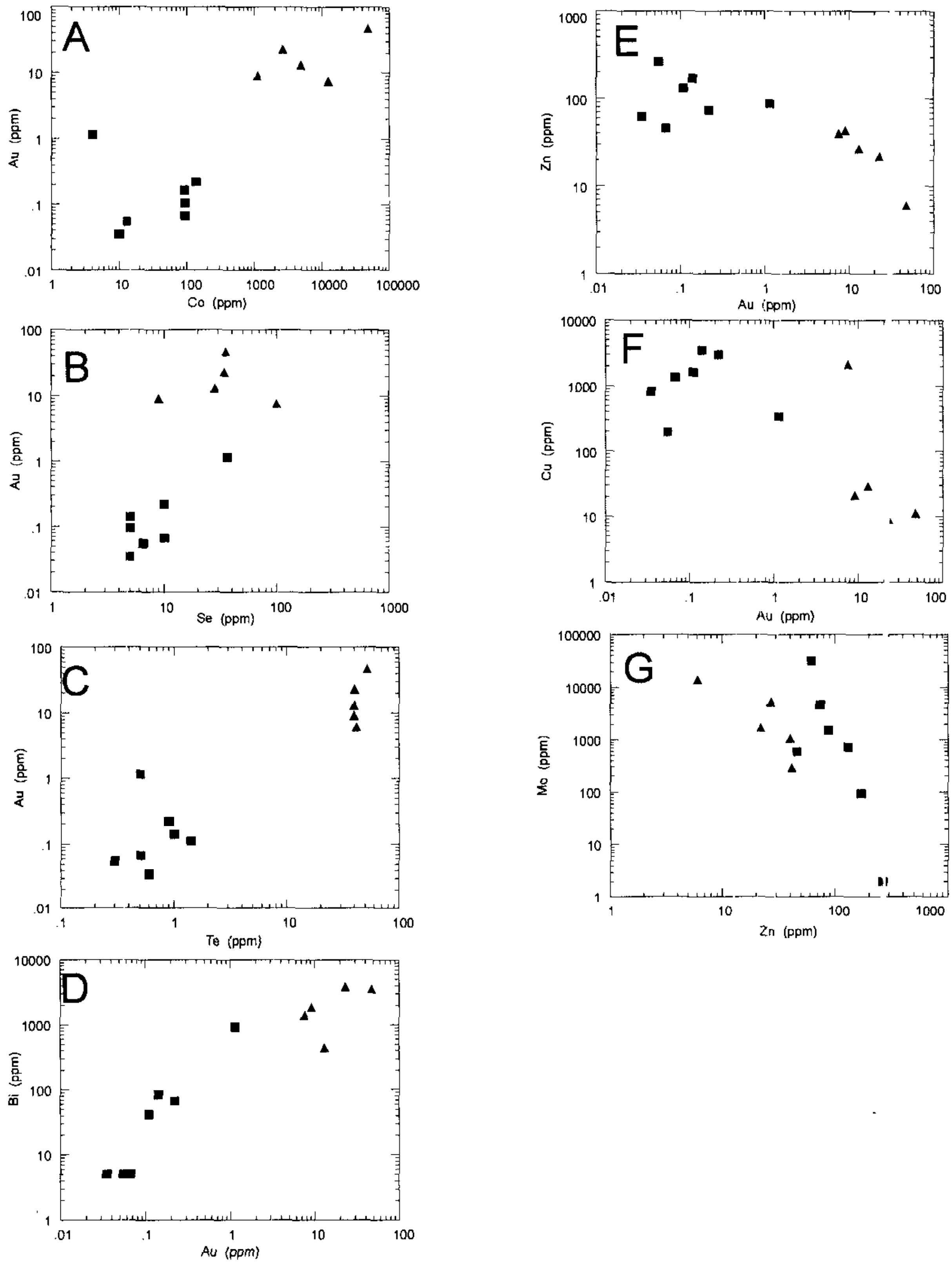


Figure 6. Plots for molybdenum skarns (triangles = gold-bearing Rossland samples; squares = other molybdneum skarn samples). A: Gold *versus* cobalt. B: Gold *versus* selenium. C: Gold *versus* tellurium. D: Bismuth *versus* gold. E: Zinc *versus* gold F: Copper *versus* gold. G: Molybdenum *versus* zinc.

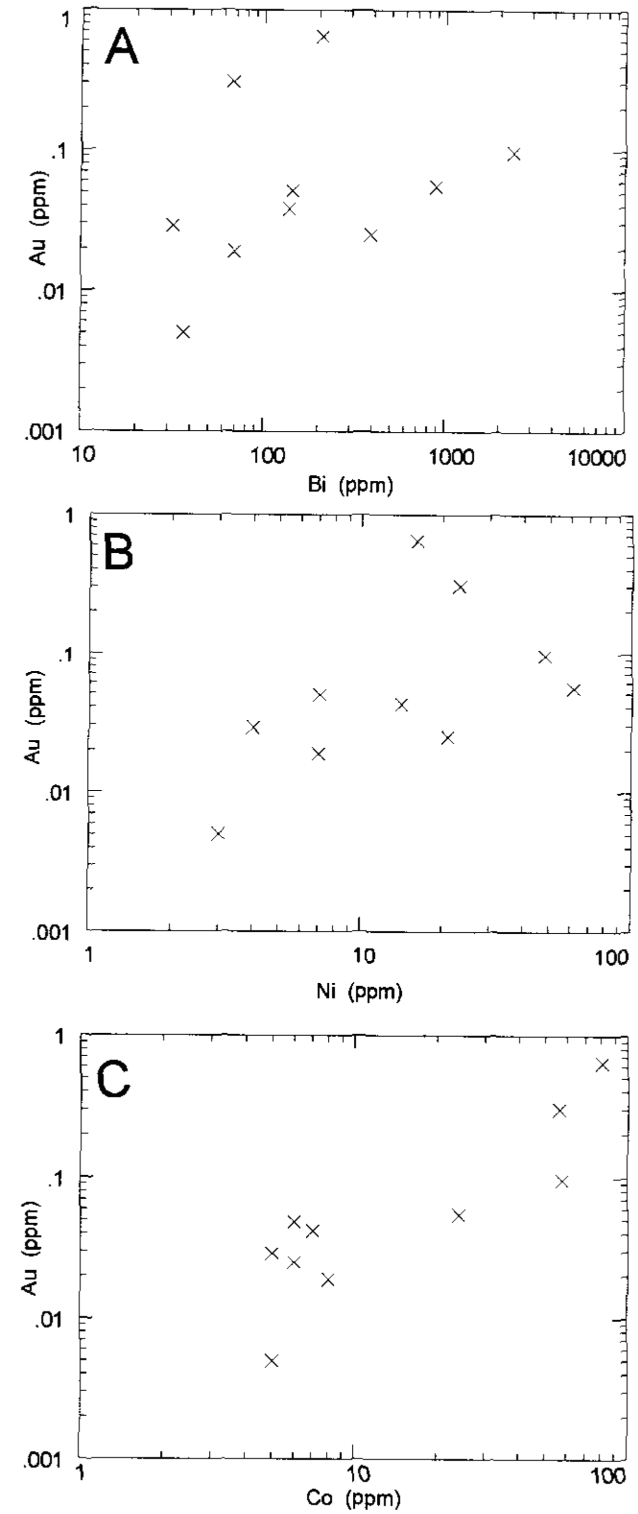


Figure 7. Plots for tin skarns. A: Gold *versus* bismuth. B: Gold *versus* nickel. C: Gold *versus* cobalt.

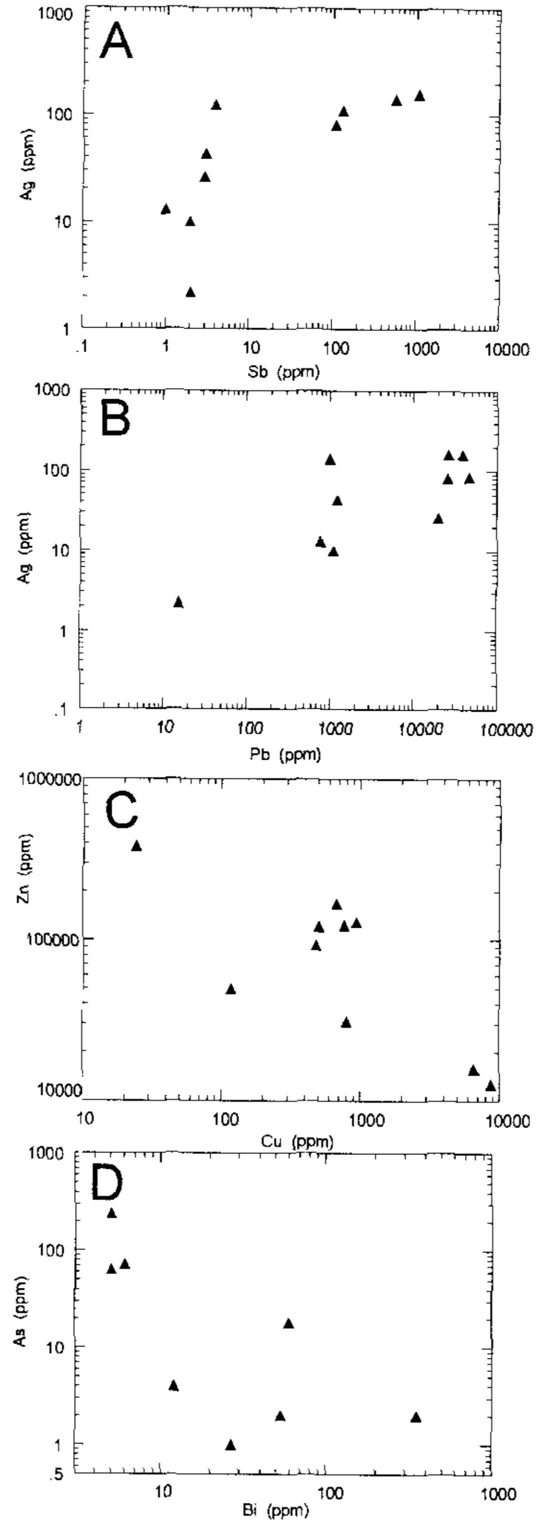


Figure 8. Plots for lead-zinc skarns. A: Silver *versus* antimony. B: Silver *versus* lead. C: Zinc *versus* copper. D: Arsenic *versus* bismuth.

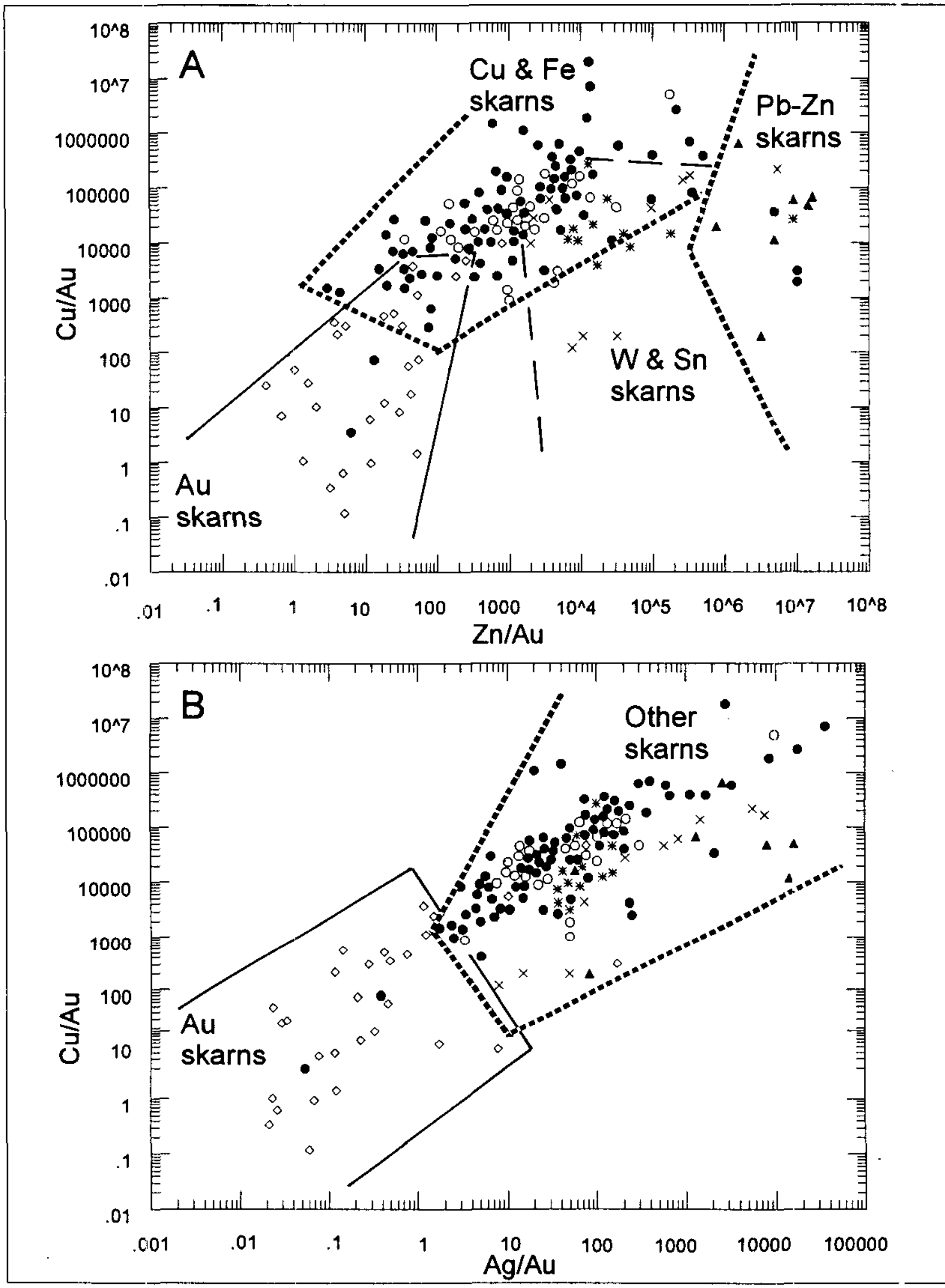
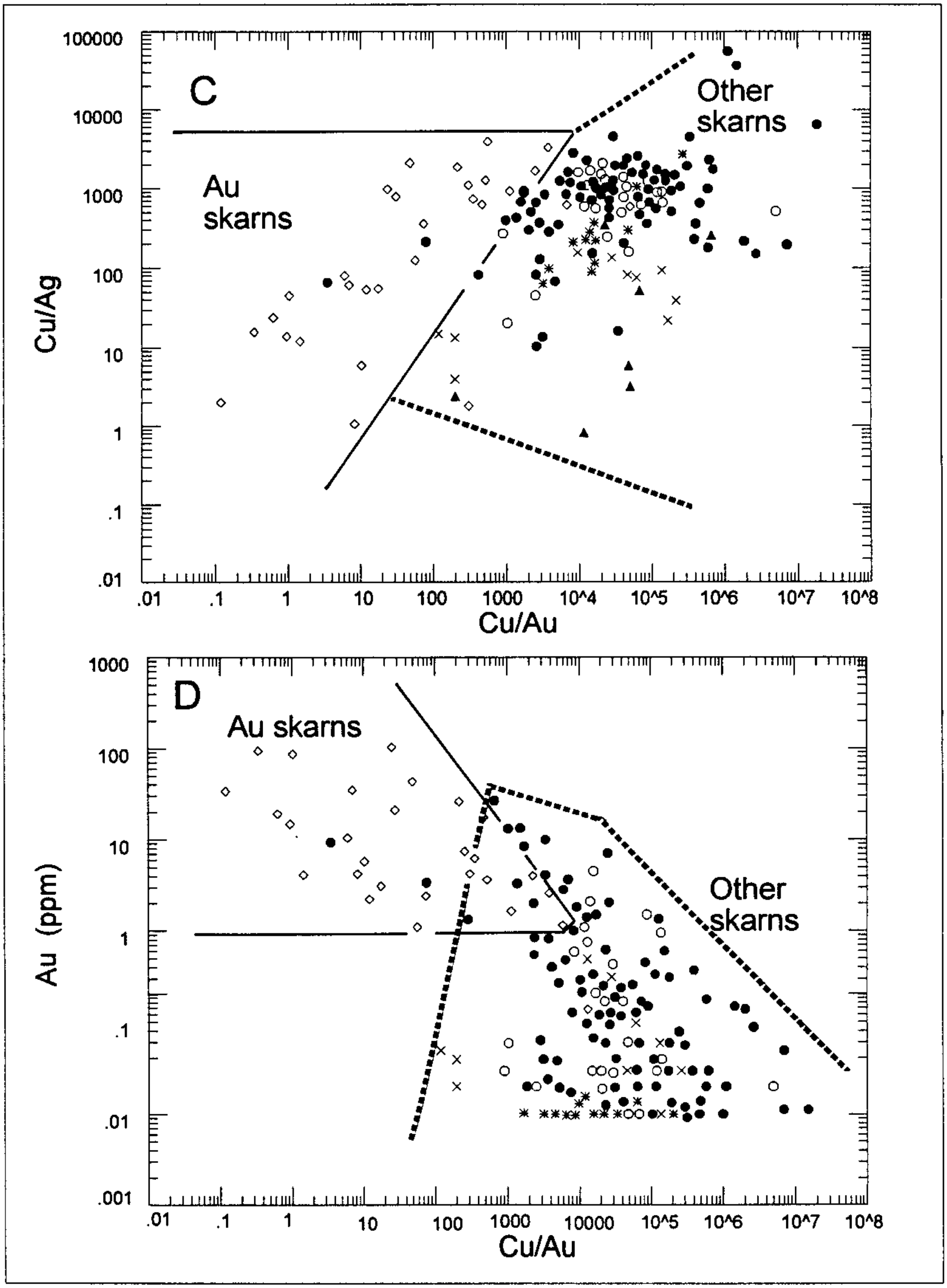


Figure 9. Plots of metal ratios for gold, iron, copper, tungsten, tin and lead-zinc skarns samples (open diamond=Au; closed circle=Cu; open circle=Fe; asteriks=W; X=Sn; triangle=Pb-Zn). A: Copper/gold versus zinc/gold. B: Copper/gold versus silver/gold. C: copper/silver versus copper/gold. D: Gold (in ppm) versus copper/gold. Note: skarn class fields have been empirically drawn around the main clustering of points.


C
Other skarns
Au skarns
Cu/Ag
Cu/Au
100000
10000
1000
100
10
1
.1
.01
.01
.1
1
10
100
1000
10^4
10^5
10^6
10^7
10^8
D
Au skarns
Other skarns
Au (ppm)
Cu/Au
1000
100
10
1
.1
.01
.001
.01
.1
1
10
100
1000
10000
10^5
10^6
10^7
10^8

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REFERENCES

Ettlinger, A.D. and Ray, G.E. (1989): Precious Metal Enriched Skarns in British Columbia: An Overview and Geological Study; *B. C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1989-3, 128 pages.

Fyles, J.T. (1984). Geological Setting of the Rossland Mining Camp; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Bulletin 74.

Meinert, L.D. (1989): Gold Skarn Deposits - Geology and Exploration Criteria; *in* The Geology of Gold Deposits; The Perspective in 1988; *Economic Geology*, Monograph 6, pages 537-552.

Myers, G.L., and Meinert, L.D. (1990): Alteration Mineralogy and Gold Distribution in the Fortitude Gold Skarn; *in* Geology and Ore Deposits of the Great Basin: Symposium Proceedings, *Geological Society of Nevada*, April 1-5, 1990, Sparks, Nevada.

Orris, G.J., Bliss, J.D., Hammarstrom, J.M. and Theodore, T.G. (1987): Description and Grades and Tonnages of Gold-bearing Skarns; *United States Geological Survey*, Open File Report 87-273, 50 pages.

Ray, G.E., Ettlinger, A.D. and Meinert, L.D. (1990) Gold Skarns: Their Distribution, Characteristics and Problems in Classification; *in* Geological Fieldwork 1989, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1990-1, pages 237-246.

Theodore, T.G., Orris, G.J., Hammarstrom, J.M. and Bliss, J.D. (1991): Gold Bearing Skarns, *United States Geological Survey*, Bulletin 1930, 61 pages.

Webster, I.C.L., Ray, G.E. and Pettipas, A.R. (1992): An Investigation of Selected Mineralized Skarns in British Columbia; *in* Geological Fieldwork 1991, Grant, B. and Newell, J.M., Editors, *B.C. Ministry of Energy, Mines and Petroleum Resources*, Paper 1992-1, pages 235-252.

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