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NICKEL AND COBALT IN PYRRHOTITE AND PYRITE FROM THE FARO AND SULLIVAN OREBODIES

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Abstract

Samples of pyrrhotite and pyrite from the Faro (Yukon) and Sullivan (British Columbia) orebodies were analyzed for nickel and cobalt by means of the electron microprobe. A total of 45 grains of each mineral from various parts of the Faro deposit average 0.02 wt.% Ni and 0.09 wt.% Co in pyrrhotite, and 0.02 wt.% Ni and 0.08 wt.% Co in pyrite. Analyses of 34 grains from stratigraphically controlled samples from the Sullivan deposit give average values of 0.03 wt.% Ni and 0.10 wt.% Co in pyrrhotite, and 0.03 wt.% Ni and 0.09 wt.% Co in pyrite. Data from the literature are used to define generalized fields for sulfides in volcanic, magmatic and sedimentary ore types. The Co/Ni ratios of samples from this study plot in a restricted area in an extension of either the sedimentary or volcanic field.

Keywords: pyrrotite, pyrite, nickel, cobalt, Sullivan, British Columbia, Faro, Yukon.

Sommaire

On a déterminé par microsonde électronique la teneur en nickel et en cobalt de la pyrrhotine et de la pyrite des gîtes Faro (Yukon) et Sullivan (Colombie-britannique). Dans le gîte Faro, la pyrrhotine contient, en moyenne, 0.02% de Ni et 0.09% de Co (en poids), tandis que la pyrite en contient 0.02 et 0.08%, respectivement (déterminations sur 45 grains de chaque espèce, provenant de diverses parties du gîte). L'analyse de 34 grains de pyrrhotine et de pyrite, bien localisés stratigraphiquement dans le gîte Sullivan, donne les moyennes 0.03% Ni, 0.10% Co et 0.03% Ni, 0.09% Co, respectivement. Les données de la littérature servent à définir les champs généralisés des sulfures dans les types de minerai volcaniques, magmatiques et sédimentaires. Si l'on reporte au diagramme les valeurs du rapport Co/Ni des échantillons, ceux-ci se trouvent groupés dans une région restreinte, extension de l'une ou l'autre de deux domaines de sulfures, l'un volcanique, l'autre sédimentaire.

(Traduit par la Rédaction)

Mots-clés: pyrrhotine, pyrite, nickel, cobalt, Sullivan, Colombie-britannique, Faro, Yukon.

Introduction

A number of investigators have sought to relate the Ni and Co contents of pyrite and pyrrhotite to environments of ore genesis and equilibration temperature of sulfides (Cambel & Jarkovsky 1968, Loftus-Hills & Solomon 1967, Tatsumi 1973). Volcanogenic pyrite typically has Co/Ni > 1, whereas sedimentary pyrite typically has Co/Ni < 1 (Loftus-Hills & Solomon 1967). Both volcanogenic and sedimentary deposits have more uniform Co and Ni levels than do hydrothermal (*i.e.*, epigenetic and presumably discordant) deposits of deep-seated origin (Cambel & Jarkovsky 1968). During metamorphism, Co is concentrated in the pyrite and Ni in the pyrrhotite (Loftus-Hills & Solomon 1967).

Despite these broad conclusions, the use of trace Co and Ni for purposes of deducing the environment of ore formation and subsequent history has had very limited success. However, trace amounts of Co and Ni in sulfide deposits may reflect the availability of the two elements in the ore-forming system and, as such, represent a signature of the metallogenic province as much as of the mode of origin.

Suites of samples from the Faro and Sullivan orebodies were analyzed to study Ni and Co values in pyrrhotite and pyrite. The analytical data were collected on an ARL–EMX electron microprobe operated at 20 kV. The standards consisted of pyrrhotite S-4, with values of 1.35 wt.% Ni and 1.35 wt.% Co, and Quemont pyrite, with values of 0.02 wt.% Ni and 0.06 wt.% Co. Five counts of 100 seconds each were taken on one or more grains in each sample. Data were reduced following the method of Bence & Albee (1968), with theoretical alpha factors for 20 kV kindly supplied to E.D. Ghent by A.L. Albee. The data were processed according to the procedure outlined by Nicholls *et al.* (1977).

Analytical Results

Faro samples

The textural relationships of pyrite and pyrrhotite in this orebody, which occurs in the Anvil Range of the Yukon Territory, are described by Campbell & Ethier (1974). The pyrite ranges from euhedral metacrysts to anhedral grains with extensive embayments of pyrrhotite. In places it is mottled and polishes poorly. This texture is interpreted as being the result of a primary sulfide assemblage modified by

TABLE 1. NICKEL AND COBALT IN PYRRHOTITE AND PYRITE, FARO DEPOSIT

Sample[1]	Ni (Po)	Co (Po)	Ni (Py)	Co (Py)	#
67-34-397	0.02	0.10	0.02	0.05	6
66-44-208	0.03	0.12	0.02	0.05	6
66-44-327	0.02	0.09	0.02	0.14	6
66-44-384	0.02	0.09	0.02	0.04	3
66-44-420	0.02	0.09	0.02	0.08	3
66-44-453	0.02	0.09	0.02	0.09	3
66-15-291	0.02	0.08	0.02	0.06	6
66-15-323	0.02	0.09	0.02	0.06	3
66-8-345	0.02	0.08	0.02	0.08	3
66-8-375	0.02	0.09	0.02	0.06	3
66-18-208	0.02	0.10	0.02	0.12	3
Average	0.02	0.09	0.02	0.08	
Average Co/Ni	4.5		4.0		

[1]First two sets of numbers indicate the drill hole, the last three digits give the footage. Po pyrrhotite, Py pyrite, # number of grains analyzed. Data reported in wt. %.

regional metamorphism followed by a contact-metamorphic event.

In Table 1, it will be noted that the results from 45 grains of each mineral are extremely uniform, although the samples came from various parts of the orebody. Partitioning of Ni in pyrrhotite and Co in pyrite during metamorphism is not apparent from these data; in fact, the Co/Ni ratio is slightly higher in pyrrhotite than in pyrite.

Sullivan samples

The details of the pyrite–pyrrhotite relationships at the Sullivan orebody in southeastern British Columbia are given by Ethier *et al.* (1976). The designation of ore bands (Fig. 1) follows that outlined by Hamilton *et al.* (1982). Table 2 presents results of microprobe analyses of trace Co and Ni in coexisting pyrite and pyrrhotite from this orebody. Average contents (in weight %) are 0.03 nickel in pyrrhotite, 0.10 cobalt in pyrrhotite, 0.03 nickel in pyrite, and 0.09 cobalt in pyrite. These data result in a Co/Ni ratio of 3.3 in pyrrhotite and 3.0 in pyrite.

The possibility of variations between laminae was studied in sample 4–8 (A band); coexisting pyrite and pyrrhotite were analyzed from four separate adjacent sulfide laminae, each a few millimetres thick. No significant variations are recognized. The stratigraphic position of 12 samples representing all 5 ore horizons (Table 2) are plotted in Figure 1. With the exception of a high Co concentration in pyrite from band D, no significant variation is detectable within the precision attained, although some suggestion of partitioning is implied by the uniformity and similar trends in, for example, Co values within the pyrrhotite and pyrite of the A band. The possibility of lateral variation was examined using a few samples from four locations; no significant differences were found.

Discussion and Conclusions

Figure 2 shows Co and Ni levels in pyrrhotite and pyrite in a variety of ore deposits, associated rock-types and modern sediments as compiled from the

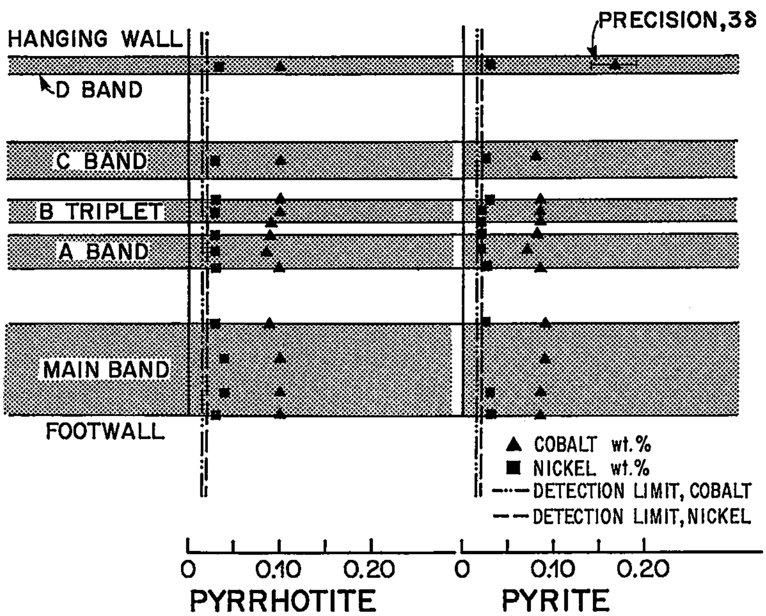

FIG. 1. Stratigraphic variation of Ni and Co in pyrrhotite and pyrite from the Sullivan orebody. Thickness of the section is approximately 30 metres.

TABLE 2. NI AND CO IN PYRRHOTITE AND PYRITE, SULLIVAN DEPOSIT

		Ni (Po)	Co (Po)	Ni (Py)	Co (Py)	#
A. between-sample variations						
4-2	Main Band	0.03	0.10	0.03	0.08	2
4-3	Main Band	0.04	0.10	0.03	0.08	2
4-4	Main Band	0.04	0.10	0.02	0.09	2
4-5	Main Band	0.03	0.09	0.03	0.09	2
4-7	A-Band	0.03	0.10	0.03	0.09	2
4-9	A-Band	0.03	0.09	0.02	0.08	3
4-11	B-1 Band	0.02	0.09	0.02	0.09	2
4-12	B-2 Band	0.03	0.10	0.02	0.08	3
4-13	B-3 Band	0.03	0.10	0.02	0.08	2
4-19	D-Band	0.03	0.10	0.03	0.17	2
14-3	Footwall	0.04	0.10	0.04	0.13	2
14-9	Footwall	0.03	0.10	0.02	0.08	1
10-1	Altered Ore	np	np	nd	0.08	1
10-6	Altered Ore	np	np	nd	0.07	2
7-160	D-Band	np	np	0.02	0.08	1
B. between-laminae variations in sample 4-8 (A-Band)						
1		0.03	0.09	0.02	0.07	1
2		0.03	0.08	0.02	0.07	1
3		np	np	nd	0.07	1
4		0.03	0.09	nd	0.07	1
5		0.03	0.09	0.02	0.08	1

Abbreviations: nd not detectable. np phase not present in sample, Po pyrrhotite. Py pyrite. # number of grains. Levels of detection: Ni 0.02 (all values of 0.02 given above are between 0.02 and 0.025), Co 0.02. Average precision (3 σ): Ni 0.03, Co 0.03.

literature (Table 3). Group A consists of compositions from volcanic and plutonic rocks and ores that can be confidently classified as volcanogenic. Most but not all of the data in this group indicate low levels of Ni (100 ppm or less). Group B consists of data for ores originating by magmatic segregation characterized by high levels of both Co and Ni. The group-C data on ancient sedimentary rocks, modern sediments and associated orebodies exhibit a wide range of Co and Ni values that are generally intermediate between groups A and B. Very preliminary and tentative fields for each group are indicated. The average Co and Ni contents of Faro and Sullivan pyrite and pyrrhotite are similar and plot between the sediment-affiliated and volcanic fields (Fig. 2).

As the boundaries of the various fields are, of necessity, somewhat arbitrary with present knowledge, the Faro and Sullivan deposits can be considered as part of either the sedimentary or volcanic group. It is apparent from Figure 2 that the Co/Ni ratio cannot be considered in isolation from the Co and Ni values, and that sedimentary iron sulfides can have Co/Ni > 1. This study and compilation show also that many more analytical data must be produced to justify generalizations concerning the identity of ore types through nickel and cobalt contents and metal ratios in iron sulfides. At the present time, the writers suggest that the fields based on

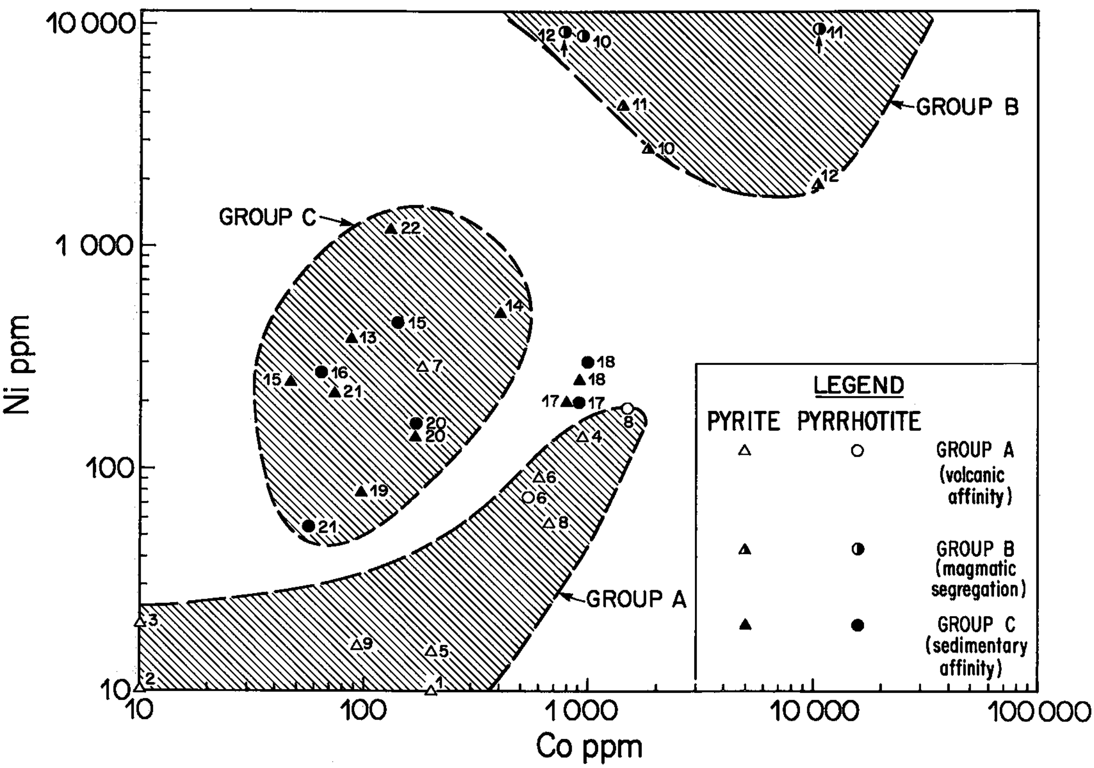

FIG. 2. Compilation of nickel and cobalt data for pyrrhotite and pyrite, showing the tentative fields for volcanic, magmatic segregation and sediment-affiliated sulfides. Note that the Faro samples (17) and Sullivan samples (18) are remarkably similar. Data-point numbers correspond to numbers of Groups A, B and C in Table 3.

TABLE 3. SUMMARY OF DATA IN FIGURE 2

Group A:	Volcanic affinity	
1.	Cambrian volcanic suite, Tasmania	(1)
2.	Stratiform volcanogenic Pb-Zn ore, Tasmania	(1)
3.	Carboniferous granite, Tasmania	(1)
4.	Texas Gulf deposit, Ontario	(2)
5.	Massive ores in ophiolites, Cyprus	(3)
6.	Noranda-Matagami areas, Quebec-Ontario	(4)
7.	Massive ores in ophiolites, York Harbour, Nfld.	(5)
8.	Flin Flon, Manitoba	(6)
9.	"Subvolcanic" ores, Czechoslovakia	(7)
Group B:	Magmatic segregation ores	
10,11.	Czechoslovakia, "liquid magmatic" type	(7)
12.	Miscellaneous, Sudbury basin	(6)
Group C:	Ancient sedimentary rocks and modern sediments	
13.	Cambrian shale, Tasmania	(1)
14.	Cambrian shale overlying ore, Tasmania	(1)
15,16.	Unmetamorphosed ore in sediments, Czechoslovakia	(7)
19.	Red Sea sediments	(9)
20.	Black Sea sediments, Pleistocene	(10)
22.	Black Sea sediments, Recent	(10)

References: (1) Loftus-Hills & Solomon (1967), (2) Farkas (1973), (3) Johnson (1972), (4) Roscoe (1965), (5) Duke & Hutchinson (1974), (6) Hawley & Nichol (1961), (7) Cambel & Jarkovsky (1968), (8) Kaplan et al. (1969), (9) Butuzova (1969), (10) Volkov & Fomina (1974).

Co/Ni ratio are incompletely defined and do not permit genetic classification of the Faro and Sullivan orebodies.

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