Mines Branch Information Circular IC 179

PRELIMINARY MINERALOGICAL STUDY OF THE SILVER DEPOSITS IN THE COBALT AREA, ONTARIO

by

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ABSTRACT

The silver deposits in the Cobalt area in Ontario consist of mineralized carbonate veins in the Cobalt series sediments, Keewatin rocks, Nipissing diabase, and lamprophyre. The central portions of the mineralized veins consist largely of cobalt-nickel arsenides and native silver in carbonate, and the terminal portions consist of arsenopyrite and sulphides in carbonate. The minerals in these veins occur in a variety of ways, but most of the cobalt-nickel arsenides occur as rosettes and masses. The rosettes in silver-bearing veins contain cores of native silver, and the masses contain irregular aggregates, disseminations and veinlets of native silver but are richer in native bismuth.

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Direction des mines

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ÉTUDE MINÉRALOGIQUE PRÉLIMINAIRE DES GISEMENTS D'ARGENT DANS LA RÉGION DE COBALT EN ONTARIO

par

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RÉSUMÉ

Les gisements d'argent de la région de Cobalt en Ontario consistent en veines de carbonate minéralisé comprises dans les sédiments de la série de Cobalt, dans les roches du Keewatin, dans la diabase Nipissing et dans des lamprophyres. La partie centrale des veines minéralisées comporte surtout des arséniures de cobalt-nickel et de l'argent natif dans du carbonate, tandis que les parties terminales comportent des arsénopyrites et des sulfures dans du carbonate. Les minéraux de ces veines se présentent de plusieurs façons, mais la majeure partie des arséniures de cobalt-nickel paraissent sous forme de rosettes et de masses. Les rosettes dans les veines argentifères ont des noyaux d'argent natif et les masses renferment de l'argent natif en agrégats irréguliers, en dissémination et en veinules mais sont plus riches en bismuth natif.

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INTRODUCTION

A mineralogical study of the silver deposits in the Cobalt and Gowganda areas in Ontario was undertaken by the writer as part of a large program conducted by the Department of Mines and Technical Surveys to provide technical assistance for the mines in those areas. This study is aimed at determining the characteristics of the deposits with a view to applying the results to exploration, ore beneficiation, and interpretation of ore genesis. As a first step the writer visited the Cobalt and Gowganda areas in October 1964, and again in August 1965, to confer with the mine operators and to collect specimens. Some 550 specimens were collected from ten operating mines and, to date, about 200 of these, from the Cobalt area, have been studied. Certain interesting characteristics have been found, and these are presented here in the form of a preliminary report to make them available at the earliest possible date. No attempt is made to describe any of the veins in detail; this will be done in later publications. Since this is a preliminary report the interpretations are subject to change.

SAMPLES

Specimens were collected from the veins in the following mines: Hi-Ho, Silverfields, Glen Lake, Nipissing 407, Agnico-Christopher, Deer Horn, Langis, O'Brien, Canadian Keeley, and Siscoe Metals of Ontario.

Preliminary studies have been made on all of the samples collected from the Hi-Ho, Glen Lake and Agnico-Christopher mines, and on some of those from the Silverfields, Deer Horn and Langis mines.

GENERAL GEOLOGY

The Cobalt area is underlain by Keewatin rocks, lamprophyre dikes, Cobalt series sediments, and Nipissing diabase (1). The Keewatin rocks are the oldest rocks in the area, and consist of basaltic lava flows and tuffs interbedded with iron formation in a few places. The iron formation consists of finely-bedded chert, slate, and greywacke, and contains disseminated chalcopyrite, sphalerite, galena and pyrrhotite. It generally occurs adjacent to terminal portions and bottom sections of mineralized veins. The lamprophyre dikes, which cut the Keewatin rocks, vary from about 2 to 20 feet in width. The Cobalt series sediments overlie the Keewatin rocks and are up to 600 feet thick; they consist of coarse to fine boulder conglomerate, greywacke, slate-like greywacke, and quartzite. Some of the boulders in the basal conglomerate are mineralized and contain disseminations of chalcopyrite, pyrrhotite and sphalerite. The Nipissing diabase is present as a sill about 1000 feet thick. It overlies the Cobalt series sediments in some places and overlies or intrudes the Keewatin rocks in other places.

COMPOSITIONS OF THE VEINS

An attempt was made to determine the compositions of the veins by analyzing a composite sample of each vein, which was made up by combining small amounts (about 10 grams) from each specimen collected from that vein. The number of specimens sampled for this purpose varied from 1 to 9 per vein. Although this cannot be regarded as a rigorous sampling procedure, it is believed that the analyses of the composite samples are fairly representative of the compositions of the veins. The methods and results of the analyses are shown in Table 1.

TABLE 1

Approximate Composition of Samples from Veins in the Cobalt Area

Mine	Vein	No. of Samples	Ag oz/ton	Fe %	Co %	Ni %	As %	Sb %	Mg %	Al %	Si %	Ca %	Cr %	Mn %	Cu %	Mo %	In %	Pb %	Bi %
Hi-Ho	Patricia	8	5033.2	4.2	9.4	16.6	24.8	1.2	0.2	0.2	0.4	5.2	tr	0.6	0.05	0.005	0.02	0.1	0.06
Hi-Ho	Cadesky (silver-rich section)	2	4602.1	1.9	6.6	27.5	24.3	1.9	0.2	0.2	0.3	4.9	0.06	0.7	0.03	0.006	0.02	0.01	0.04
Glen Lake	405-506	3	480.4	13.7	3.8	4.3	42.8	<1	-	0.1	0.4	3.5	0.01	0.1	0.05	0.005	0.01	0.2	0.08
Glen Lake	504E (vein end)	3	84.4	9.7	2.6	<1	11.5	≪1	0.2	0.2	0.4	6.6	0.07	0.05	0.04	0.005	0.01	0.1	0.16
Glen Lake	403N (vein end)	5	1066.5	11.3	6.2	4.0	21.4	<1	-	0.2	0.4	6.6	0.01	0.09	0.03	0.004	0.02	0.2	0.11
Deer Horn	506	6	4138.3	2.5	2.4	3.6	3.9	2.9	-	0.2	0.4	7.6	ND	0.06	0.07	0.003	0.02	0.1	0.05
Agnico-Christopher	470 (silver-rich section)	3	1891.9	4.3	3.2	<1	6.2	1.5	-	0.2	0.5	9.1	ND	0.09	0.07	0.005	0.02	0.1	0.03
Agnico-Christopher	470 (massive cobalt section)	4	2.2	10.0	12.9	3.4	33.3	≪1	-	0.2	0.3	4.9	0.05	0.03	0.03	0.005	0.01	0.1	0.14
Langis	30	8	124.6	27.9	1.7	1.0	2.6	≪1	-	0.2	0.5	5.2	0.1	0.09	0.05	0.005	0.01	0.2	0.03
Langis	37	9	16.3	4.4	10.5	4.9	19.8	<1	-	0.2	0.3	4.8	0.01	0.09	0.03	0.009	0.02	0.1	0.12
Langis	90	1	8361.8	2.3	6.9	6.6	13.3	<1	-	0.2	0.4	5.3	0.01	0.09	0.03	0.007	0.02	0.01	0.003

The silver analyses were made by the fire assay method; results are from MSD Internal Report MS-AC-65-699 by L. Lutes and C. Derry (1965).

Fe, Co, Ni As and Sb were determined by X-ray fluorescence analysis; results from MSD Internal Report SL-65-076 by Mrs. D. J. Reed (1965).

The remaining elements were analyzed semi-quantitatively by emission spectrography; results from MSD Internal Report SL-65-120 by D. Palombo (1965).

The analytical results show that there are wide variations in composition, including the silver content. There is an apparent tendency for the samples with the highest silver content to contain the most antimony, and those with lower silver contents to contain the most bismuth, although this correlation is not completely consistent.

GENERAL CHARACTERISTICS OF THE DEPOSITS

The deposits consist of mineralized carbonate veins which occur in the Cobalt series of sediments, Keewatin volcanic rocks and iron formation, Nipissing diabase, and lamprophyre dikes. The mineralized veins are generally nearly vertical. They vary from a fraction of an inch to about 12 inches in width, and are up to several hundred feet in both vertical and horizontal extent. Some veins occur singly, while others occur in groups. Generally the central portions, terminal portions and edges of the veins have distinct mineral associations, but these associations are gradational from one type to another. The central portions consist largely of cobalt-nickel arsenides and native silver in a carbonate matrix, the terminal portions of arsenopyrite and sulphides in a carbonate matrix, and the edges of sulphides in carbonate. In some places the mineral associations of the terminal portions extend for several tens of feet, but in other places they are absent. Those of the edges are also present only intermittently, but are most abundant near the terminal portions.

DETAILED CHARACTERISTICS OF THE VEINS

Ore Minerals in the Central Portions

The ore minerals in the central portions of the veins occur in a wide variety of ways, which can be summarized as follows:

(1) Rosettes of cobalt and/or nickel arsenides with cores of native silver

(2) Masses of cobalt-nickel arsenides with inclusions of native silver

(3) Intricate networks of silver-bearing veinlets in dolomite

(4) Sheet-like veinlets of native silver in safflorite, wall rock and calcite

(5) Massive native silver and tetrahedrite in calcite

(6) Wire silver

(7) Disseminated silver sulphantimonides, sulphides and native silver in siderite

(8) Rosettes of cobalt arsenides with little or no silver

(9) Masses of cobalt, nickel and iron arsenides with little or no silver

(10) Disseminated grains of cobalt and iron arsenides in calcite

(11) Disseminated grains, masses and veinlets of arsenides, silver-sulphantimonides, native silver and sulphides in carbonate

(12) Sulphide veinlets in calcite veins.

Veins having the features listed above from 1 to 7 inclusive, usually contain large amounts of silver, while those having features 8 to 10 inclusive contain little or no silver but are enriched in bismuth. The feature numbered 11 is characteristic of the terminal portions of most of the veins studied. Number 12 is characteristic of late-fault veins. The various features observed in the veins studied are listed in Table 2. Most of the veins exhibit more than one of the features.

TABLE 2

Features of the Veins Studied

Mine	Vein	Host Rock	Features*
Hi-Ho	Patricia	Cobalt sediments	1,2,3, and 4
Hi-Ho	Cadesky	Cobalt sediments	9,8,1,2, and 3
Hi-Ho	21	Cobalt sediments	11
Hi-Ho	F-13	Cobalt sediments	1
Silverfields	401 and 405	Cobalt sediments	1, and 2
Silverfields	501	Cobalt sediments	2, and 4
Glen Lake	406	--	2, and 4
Deer Horn	506N	Keewatin tuff	1, and 9
Agnico-Christopher	470	Keewatin flows	9
Agnico-Christopher	470	Lamprophyre	2,4,5, and 9
Agnico-Christopher	407	--	7
Langis	37	Cobalt sediments	8, and 10
Langis	30	Keewatin	7, and 12
Langis	355-20	--	2

* The numbers correspond to the features listed above, and they are given according to their order of abundance within the vein.

Detailed descriptions of the twelve features are as follows:

(1) Rosettes of Cobalt and/or Nickel Arsenides with Cores of Native Silver

Rosettes of cobalt and/or nickel arsenides with cores of native silver are a relatively common feature in many veins. They are present as discrete individuals in a carbonate matrix (Figure 1), as loosely combined individuals, and as masses of coalesced rosettes (Figure 2). They usually occur as irregular aggregates in the central parts of the veins, but a sample from vein 355-20 in the Langis mine showed rosettes arranged in a linear aggregate like a string of beads (Figure 3).

The rosettes are composed of an outer portion and a core. The outer portion usually consists of safflorite, but sometimes of cobaltite and ullmannite (vein 506N in the Deer Horn mine, Figure 1). In some places the safflorite is free of impurities, in others it contains minute grains of cobaltite, and in still others it contains small grains of skutterudite and cobaltite.

The cores consist of native silver associated with niccolite and breithauptite, native silver associated with pararammelsbergite, native silver associated with calcite, and native silver alone. The silver associated with niccolite and breithauptite is present in both the niccolite (Figure 2) and breithauptite, while that associated with pararammelsbergite occurs along safflorite-pararammelsbergite grain boundaries (Figure 4). The silver occurring alone is generally present as irregular grains, but sometimes as cruciform aggregates (Figure 3).

In general, the silver has highly irregular contacts with niccolite and safflorite, whereas the contacts with pararammelsbergite and skutterudite are quite regular (Figure 5). This suggests that the silver preferentially replaced niccolite and safflorite.

Most of the silver contains irregular bodies composed of dyscrasite and a silver-bearing mineral that has not yet been identified (Figure 6). The dyscrasite is present as lamellae in the unknown silver-bearing mineral, and as borders around the irregular bodies. The unknown silver-bearing mineral has a slightly lower reflectivity than native silver, but its X-ray diffraction pattern is similar to that of native silver.

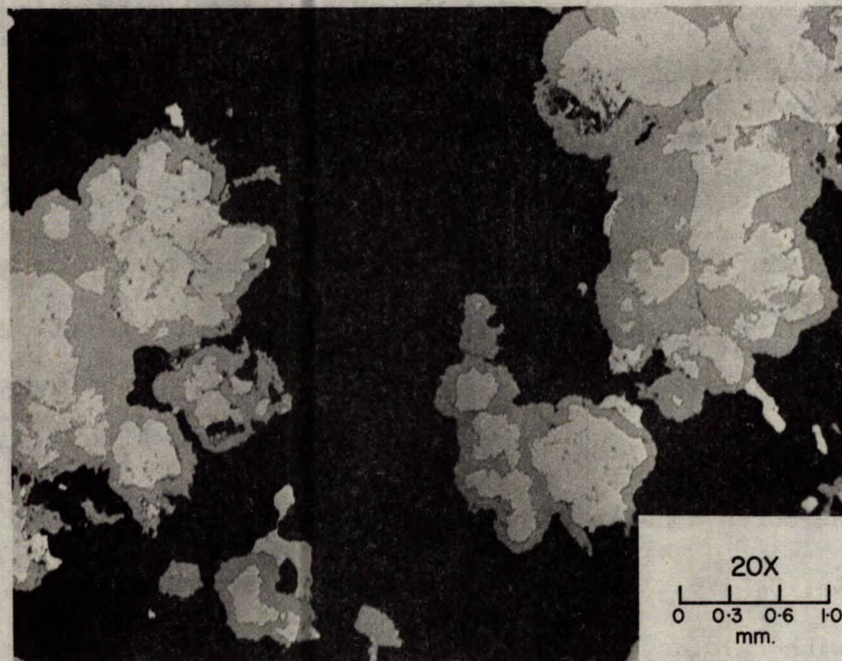

Figure 1. Photomicrograph of a polished section showing rosettes from vein 506N in the Deer Horn mine. The rosettes consist of cobaltite and/or ullmannite (grey) with cores of native silver (white). The black area represents dolomite.

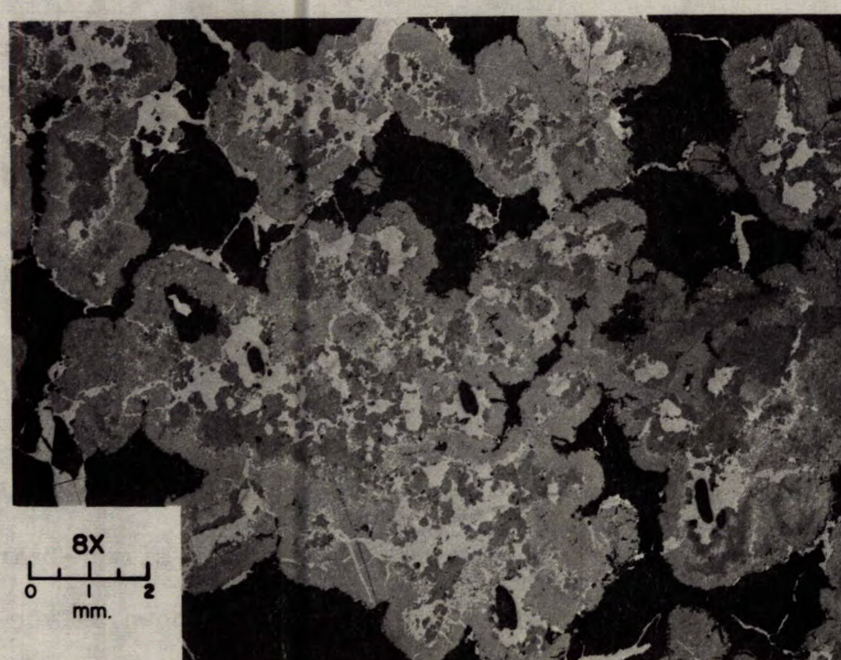

Figure 2. Photomicrograph of a polished section of a sample from the Patricia vein in the Hi-Ho mine, showing a group of loosely combined individuals and small masses of coalesced rosettes in carbonate (black). The rosettes consist of safflorite (light grey) around cores of native silver (white) associated with niccolite (dark grey). Some native silver is also present outside the rosettes.

In some places, particularly near the terminal portions and edges of the veins, the native silver is replaced by tetrahedrite and pyrargyrite.

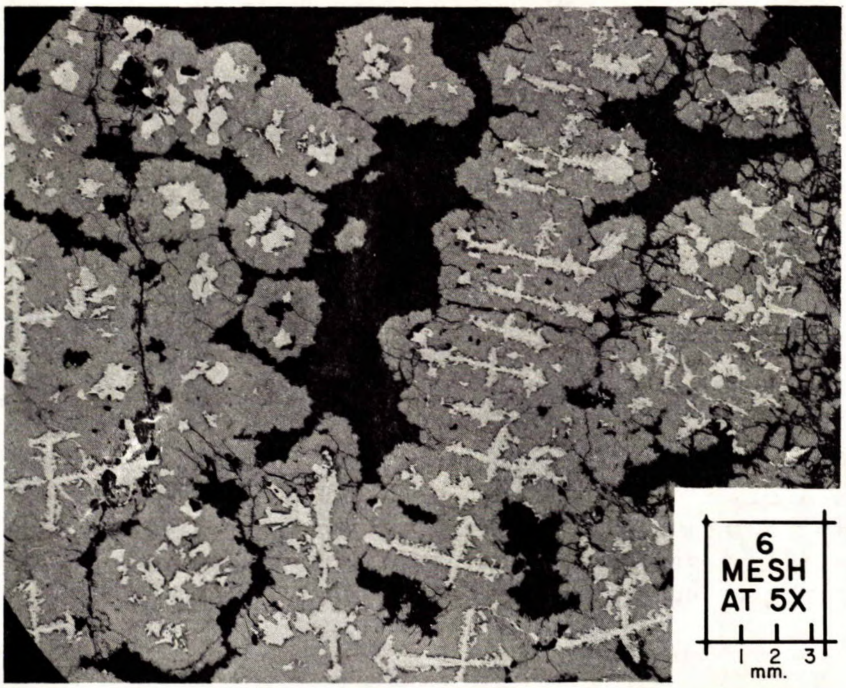

Figure 3. Photomicrograph of a polished section showing linear aggregates of rosettes from vein 355-20 in the Langis mine. The rosettes consist of safflorite (grey) with cruciform cores of native silver (white). The black areas represent carbonate.

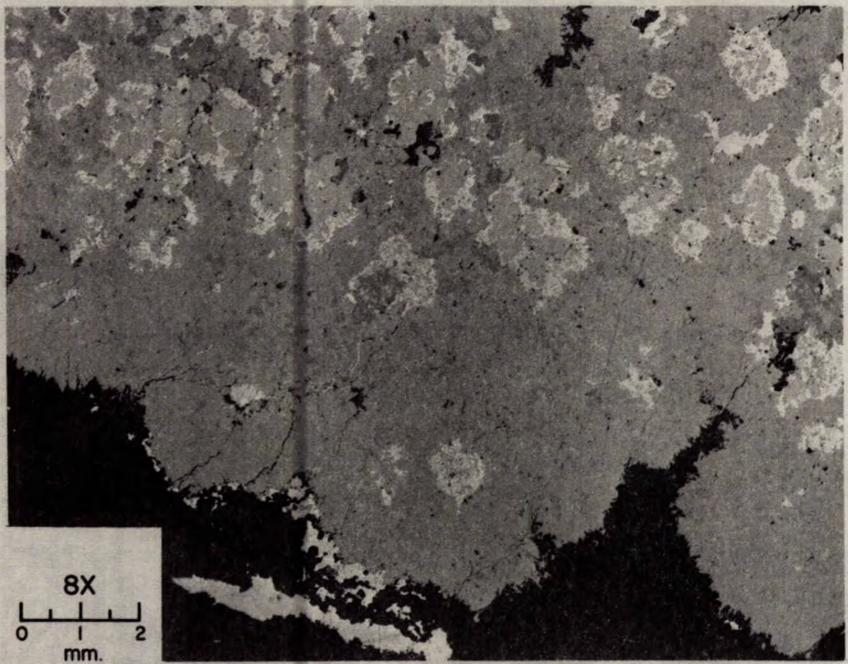

Figure 4. Photomicrograph of a polished section showing a mass of safflorite composed of a cluster of rosettes, from the Silverfields mine. The safflorite (grey) contains inclusions of native silver (white) associated with pararammelsbergite (light grey). The native silver follows the safflorite-pararammelsbergite boundary.

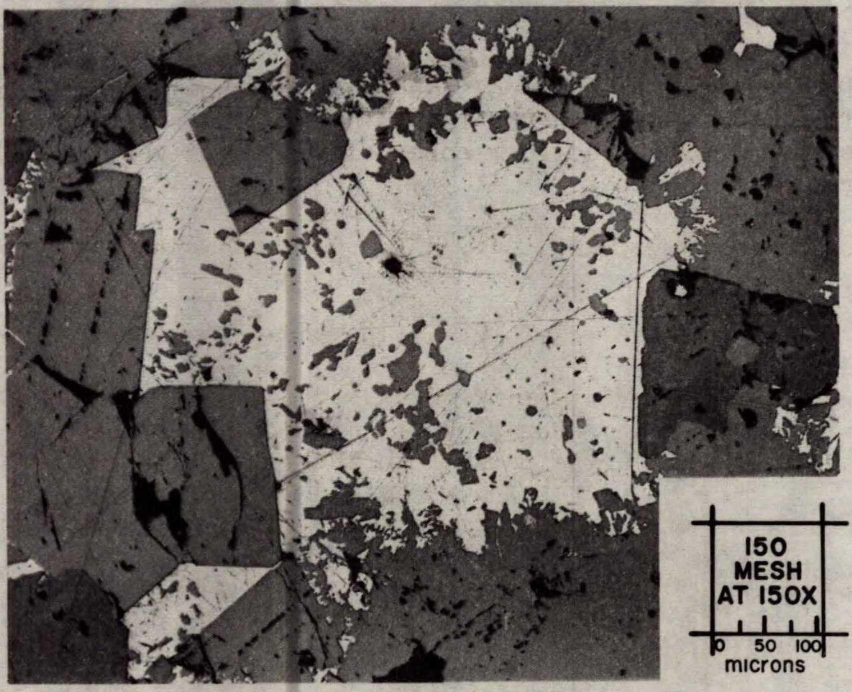

Figure 5. Photomicrograph of a polished section at high magnification in immersion oil, showing native silver (white) in safflorite (grey) and skutterudite (grey euhedral crystals). The silver-safflorite boundary is irregular, whereas the silver-skutterudite boundary is regular.

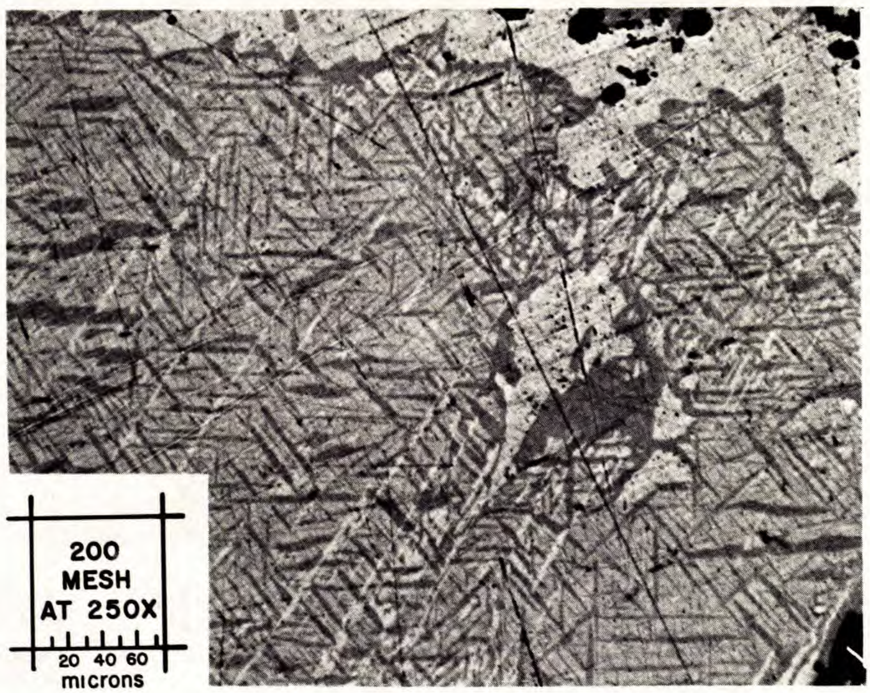

Figure 6. Photomicrograph of a polished section showing native silver (white) with an irregular body composed of dyscrasite (dark grey) and a silver-bearing mineral (light grey). The dyscrasite is present as lamellae in the silver-bearing mineral and as borders around the irregular body. This photograph was taken by using immersion oil and high-contrast film to enhance contrast.

(2) Masses of Cobalt-Nickel Arsenides with Inclusions of Native Silver

Masses of arsenides with inclusions of native silver are also a relatively common feature in many veins. The masses consist of intricate intergrowths of the minerals present in the veins. Those in vein 470 in the Agnico-Christopher mine consist of safflorite and native silver, those in veins 401, 405 and 501 in the Silverfields mine consist of safflorite, pararammelsbergite, skutterudite, cobaltite, and native silver (Figure 7), and those in veins 408W and 406 in the Glen Lake mine consist of safflorite, niccolite, skutterudite, cobaltite, and native silver (Figure 8).

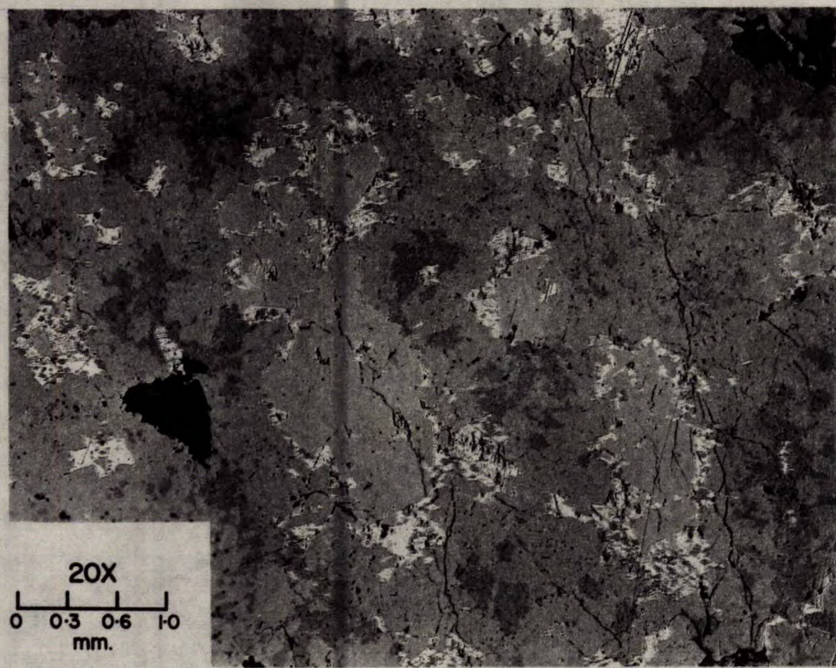

Figure 7. Photomicrograph of a polished section of massive arsenides from the Silverfields mine. The white areas represent native silver, and the various shades of grey represent pararammelsbergite, safflorite, skutterudite, and cobaltite.

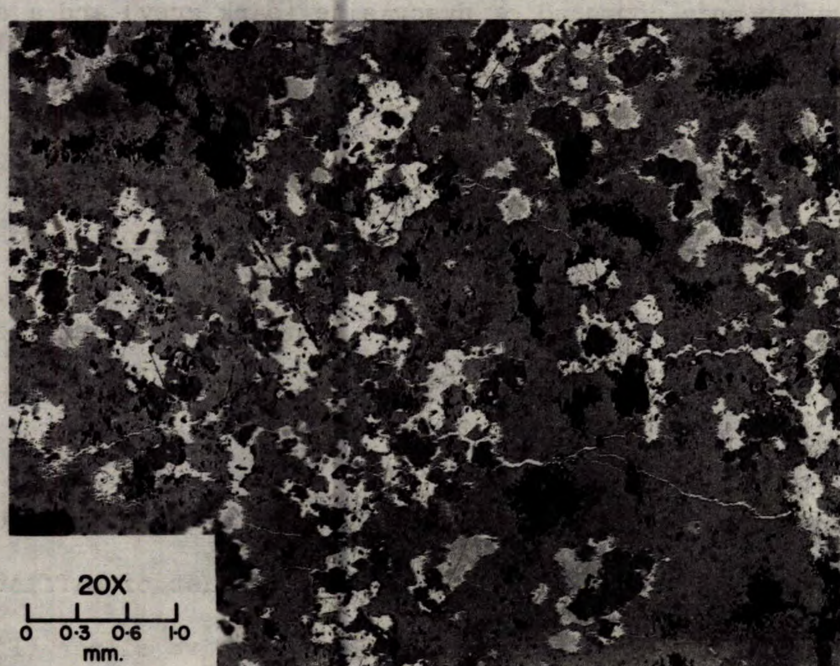

Figure 8. Photomicrograph of a polished section of massive cobalt and nickel arsenides from vein 408W, Glen Lake mine. It shows safflorite, skutterudite and cobaltite (shades of grey), native silver (white), and niccolite (dark grey). The black areas represent carbonate.

(3) Intricate Networks of Silver-Bearing Veinlets in Dolomite

Intricate networks of silver-bearing veinlets in dolomite are generally present in the high-grade silver veins (see Figure 9). The network may extend across the entire width of the vein, but the veinlets generally do not cut across masses and rosettes of arsenides.

(4) Sheet-like Veinlets of Native Silver in Safflorite, Wall Rock and Calcite

Sheet-like veinlets of native silver are present in safflorite and calcite veins. Those in the safflorite veins are embedded in safflorite and generally extend into the wall rock (Figure 10). They are up to 1/4 inch thick and several inches long. Veinlets of this type are present in vein 501 in the Silverfields mine, vein 406 in the Glen Lake mine, and the lower section of the Patricia vein in the Hi-Ho mine.

One sheet-like veinlet of native silver in calcite was found in vein 470, Agnico-Christopher mine. This veinlet is about 1/8 to 1/4 inch thick and about 6 inches long. The silver contains numerous dyscrasite lamellae, and is coated with tetrahedrite. The tetrahedrite is greyish black in hand specimens and has a vitreous lustre.

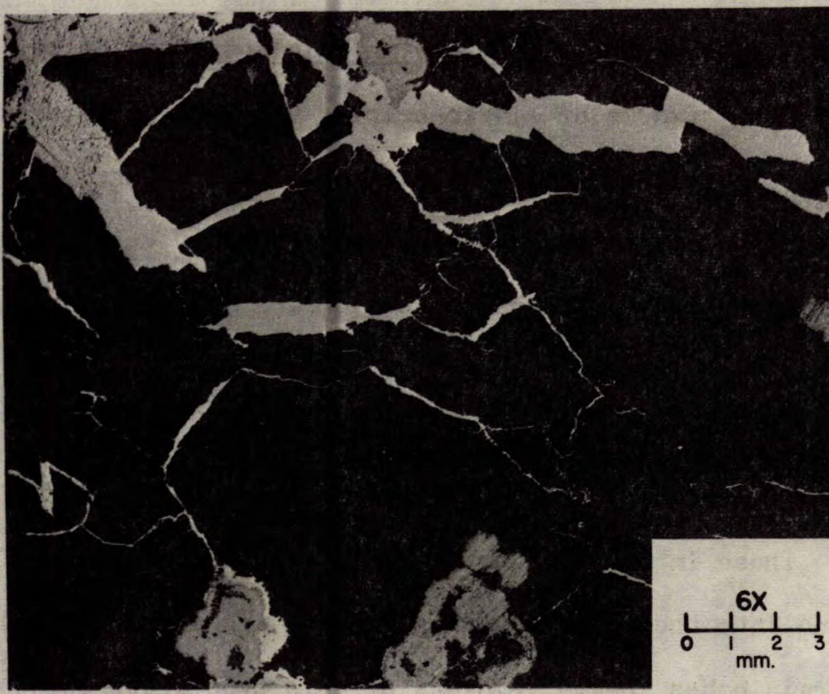

Figure 9. Photomicrograph of a polished section of the Patricia vein in the Hi-Ho mine, showing a network of silver-bearing veinlets (white) in dolomite (black). The white area represents dyscrasite and the unknown silver-bearing mineral, and the white mottled area in the upper left hand corner represents native silver. The grey areas represent safflorite.

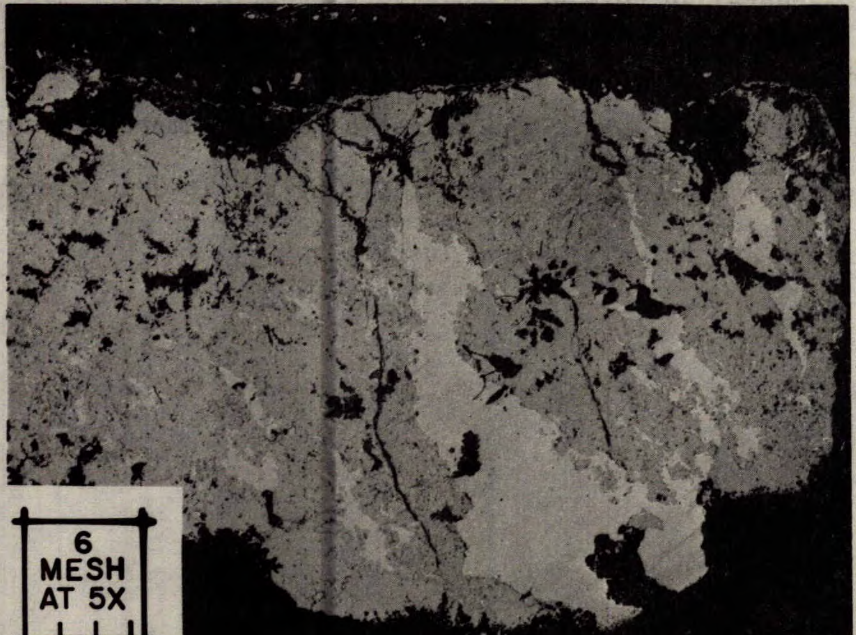

Figure 10. Photomicrograph of a polished section of part of vein 406 in the Glen Lake mine, showing veinlets of native silver (white) in safflorite (grey).

(5) Massive Native Silver and Tetrahedrite in Calcite

Masses and disseminated grains of tetrahedrite, and masses of native silver with dyscrasite lamellae, are present in calcite in part of vein 470 in the Agnico-Christopher mine (Figure 11). The tetrahedrite is greyish- to brownish-black in hand specimens and has a vitreous to dull lustre.

(6) Wire Silver

Two samples of wire silver were given to the writer by the mine operators. The wire silver in one sample was embedded in rhombohedral calcite crystals in a calcite vein which cut a mineralized rock. The wires are flattened and are about 1 millimetre wide, 1/4 millimetre thick, and 1 inch long. The wire silver in the other sample consisted of short loose wires. The loose wires are rounded and are about 0.1 millimetre in diameter. They are intergrown with tetrahedrite and arsenopyrite.

(7) Disseminated Silver-Sulphantimonides, Sulphides and Native Silver in Siderite

Disseminated grains of silver-sulphantimonides, sulphides and native silver were found in samples from vein 30 in the Langis mine, and vein 407 in the Agnico-Christopher mine. The siderite from the Langis mine is reddish-black in hand specimens and contains disseminated grains of pyrargyrite, stephanite, acanthite, native silver, tetrahedrite, chalcopyrite, galena and marcasite (Figure 12). The siderite from the Agnico-Christopher mine occurs as nodules and contains disseminated grains of xanthocanite, pyrite, arsenopyrite, marcasite, acanthite, glaucodot and galena (Figure 13).

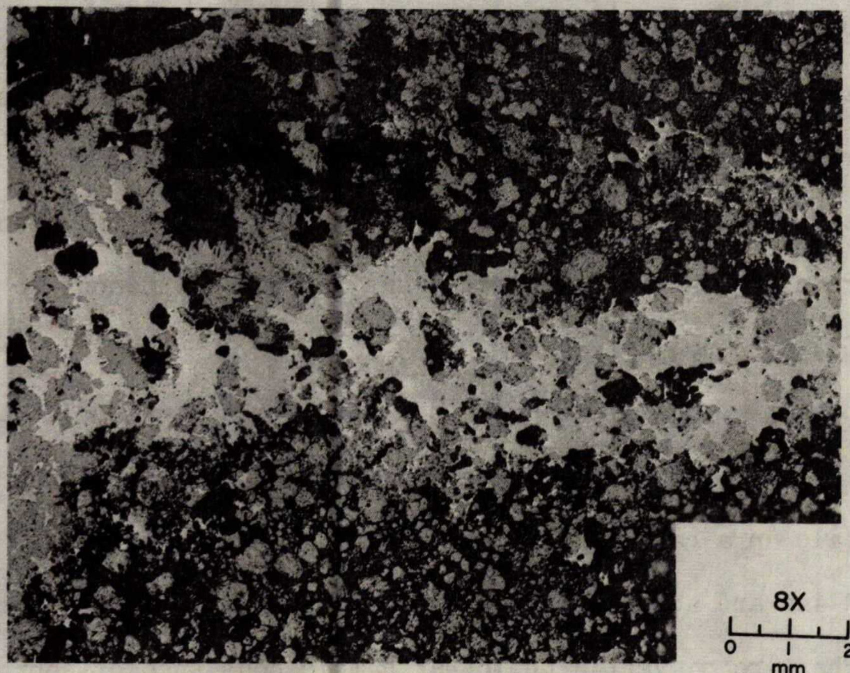

Figure 11. Photomicrograph of a polished section of part of vein 470 in the Agnico-Christopher mine. This section of the vein consists of heavily disseminated tetrahedrite (grey) in calcite (black); with some irregular masses of native silver (white).

Figure 12. Photomicrograph of a polished section of mineralized siderite in vein 30 in the Langis mine. The siderite (grey) contains disseminated grains of pyrargyrite, acanthite, stephanite and tetrahedrite (white).

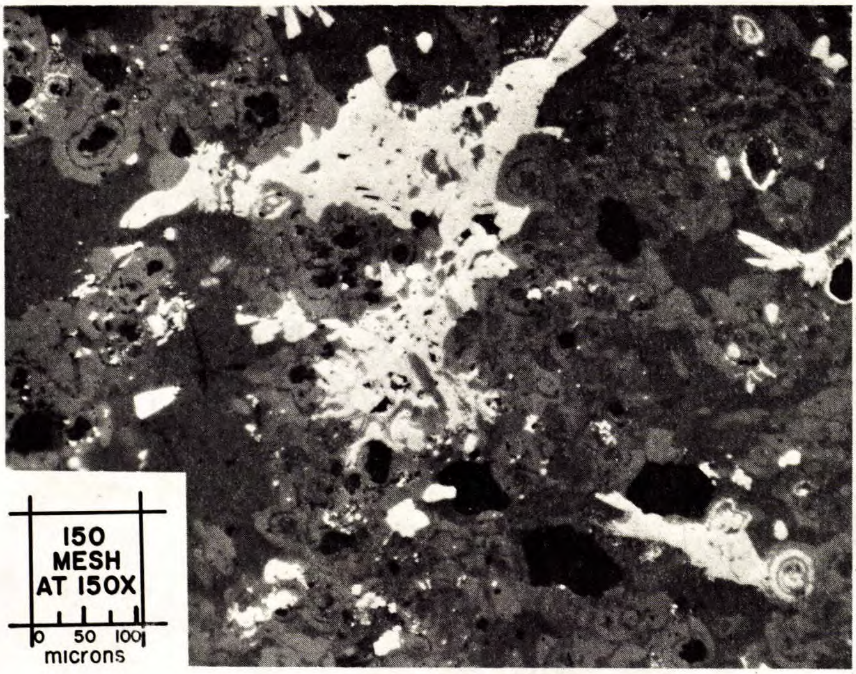

Figure 13. Photomicrograph of a polished section showing mineralized siderite (grey) in a mounting medium (dark grey). The siderite contains several large xanthoconite grains and a few small pyrite and chalcopyrite grains (white).

(8) <u>Rosettes of Cobalt Arsenides with Little or No Silver</u>

Rosettes of cobalt arsenides with little or no silver are present in a few places. Some of them consist chiefly of safflorite, and others of skutterudite and cobaltite. The former are generally composed of radial safflorite crystals around skutterudite and contain some cobaltite (Cadesky vein, Hi-Ho mine (Figures 14 and 15)). In hand specimens they have similar textures and structures to the silver-bearing rosettes but the silver-bearing ones contain visible silver, and on broken surfaces the native silver has a jagged edge and feels like a rasp.

The skutterudite-cobaltite rosettes consist of an outer layer of skutterudite, an inner layer of cobaltite, and a calcite core (Figure 16). They are present in vein 37 in the Langis mine, where they occur as linear aggregates similar to strings of beads (Figure 17).

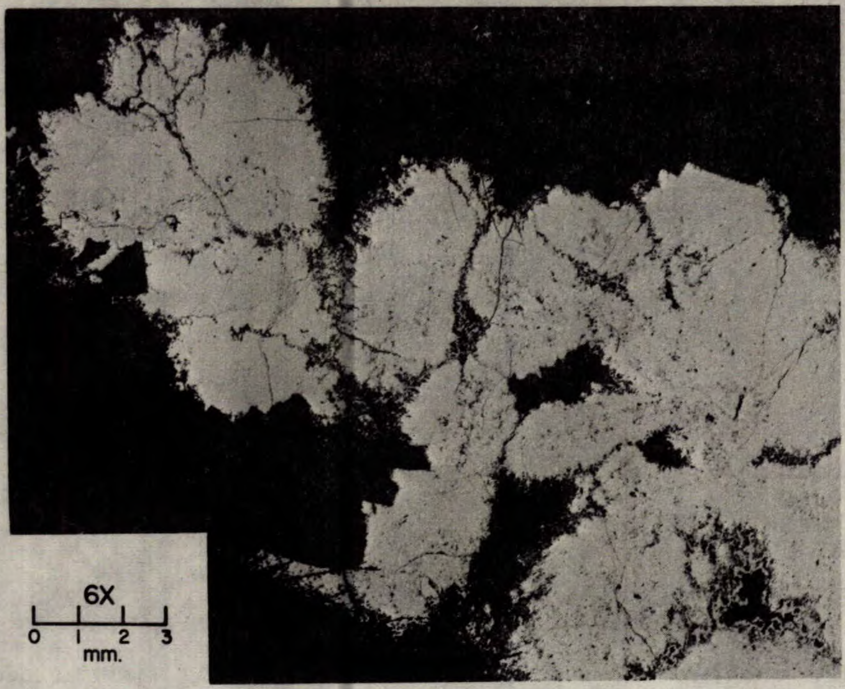

Figure 14. Photomicrograph of a polished section of rosettes of cobalt arsenides in the Cadesky vein in the Hi-Ho mine. The rosettes consist largely of safflorite and contain cores of skutterudite. The skutterudite and safflorite cannot be differentiated on this photomicrograph.

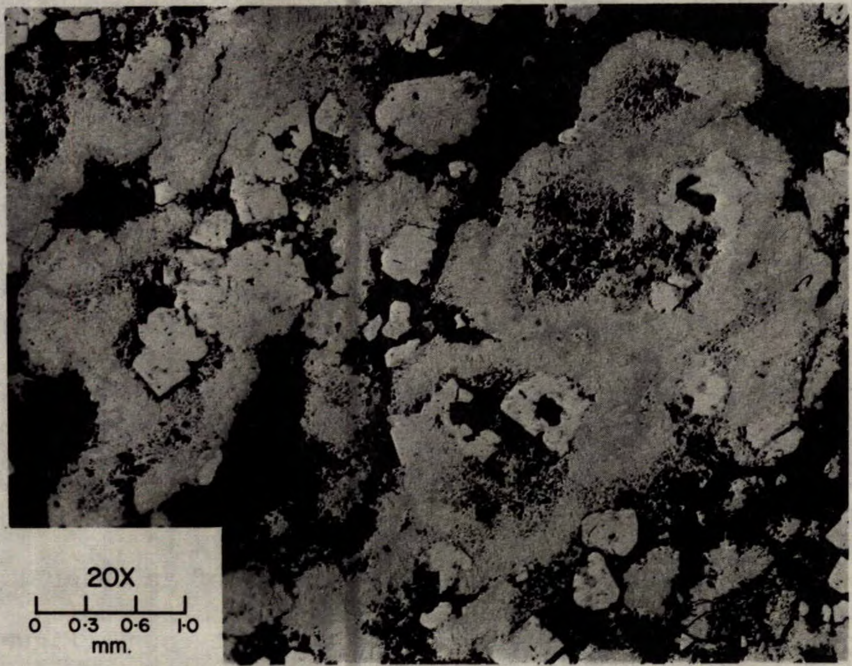

Figure 15. Photomicrograph of a polished section of poorly developed rosettes of cobalt arsenides in the Cadesky vein in the Hi-Ho mine. The rosettes consist of safflorite and cobaltite (shades of grey), and contain euhedral skutterudite crystals. The black area represents dolomite and calcite.

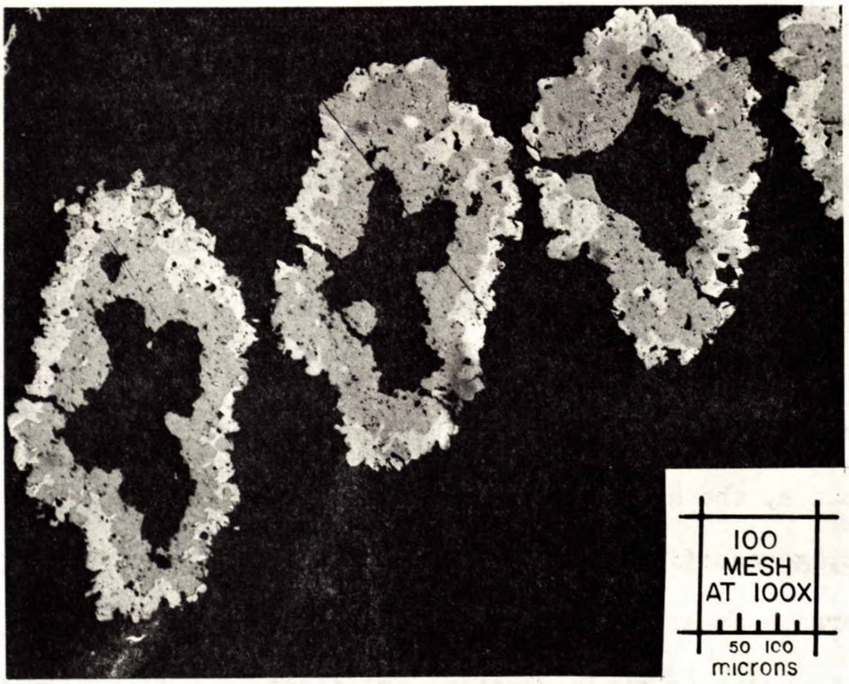

Figure 16. Photomicrograph of a polished section of vein 37 in the Langis mine, showing three rosettes in calcite (black). They consist of cores of calcite (black), surrounded by cobaltite (grey) and skutterudite (white).

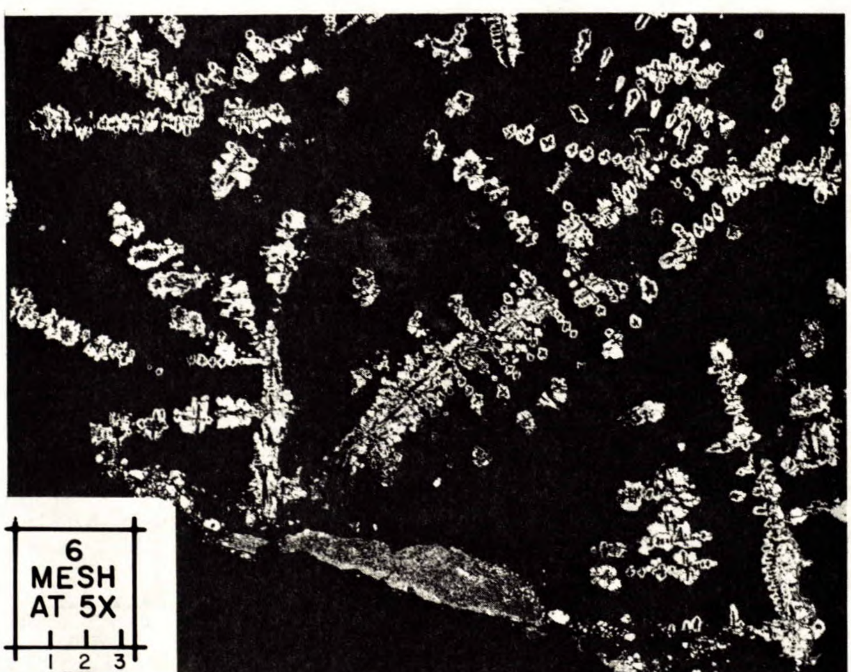

Figure 17. Photomicrograph of a polished section of vein 37 in the Langis mine, showing the rosettes referred to in Figure 16, arranged like strings of beads in a dendritic-like pattern (white). The black area represents calcite.

(9) Masses of Cobalt, Nickel and Iron Arsenides with Little or No Silver

Masses of cobalt, nickel, and iron arsenides are present in a number of arsenide veins. The masses are composed of safflorite, skutterudite, cobaltite, gersdorffite, niccolite, breithauptite, rammelsbergite, pararammelsbergite and arsenopyrite, and in a few places contain veinlets, masses and crystals of native bismuth (Figure 18). The safflorite occurs as masses and radial crystals around skutterudite, the skutterudite as masses and euhedral crystals, the arsenopyrite as veinlets and euhedral crystals, and the cobaltite, gersdorffite, niccolite, breithauptite, rammelsbergite and pararammelsbergite as irregular masses (Figures 19 and 20). Some of the euhedral skutterudite crystals contain inclusions of native bismuth, native silver, tetrahedrite and chalcopyrite.

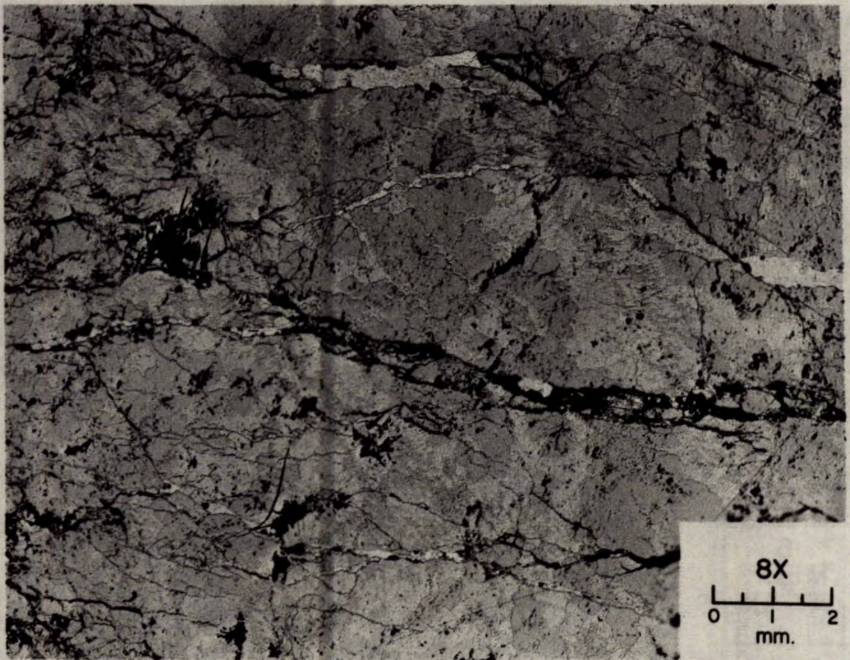

Figure 18. Photomicrograph of a polished section of massive cobalt arsenides with veinlets of native bismuth (white) and carbonate (black). The arsenides are safflorite (light grey) and cobaltite (darker grey).

The masses of arsenides are abundant in the Cadesky vein of the Hi-Ho mine, in vein 470 of the Agnico-Christopher mine, in a vein in the Dolphin-Miller mine, and in an ore disposal dump near the Nipissing mine that was worked several decades ago. These veins vary from about 2 to 12 inches in width.

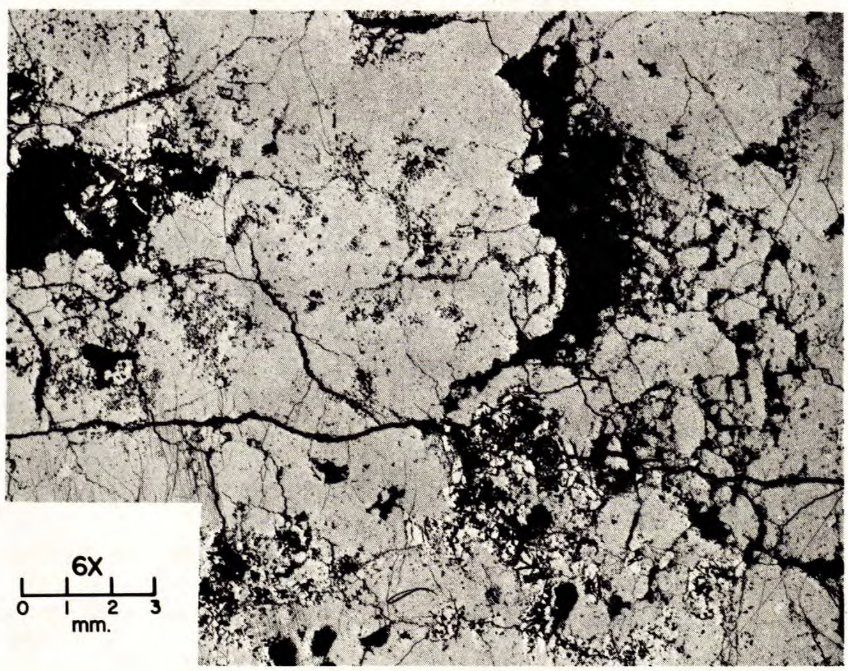

Figure 19. Photomicrograph of a polished section showing massive cobaltite (light grey) with minute euhedral crystals of skutterudite (white). The black areas represent dolomite.

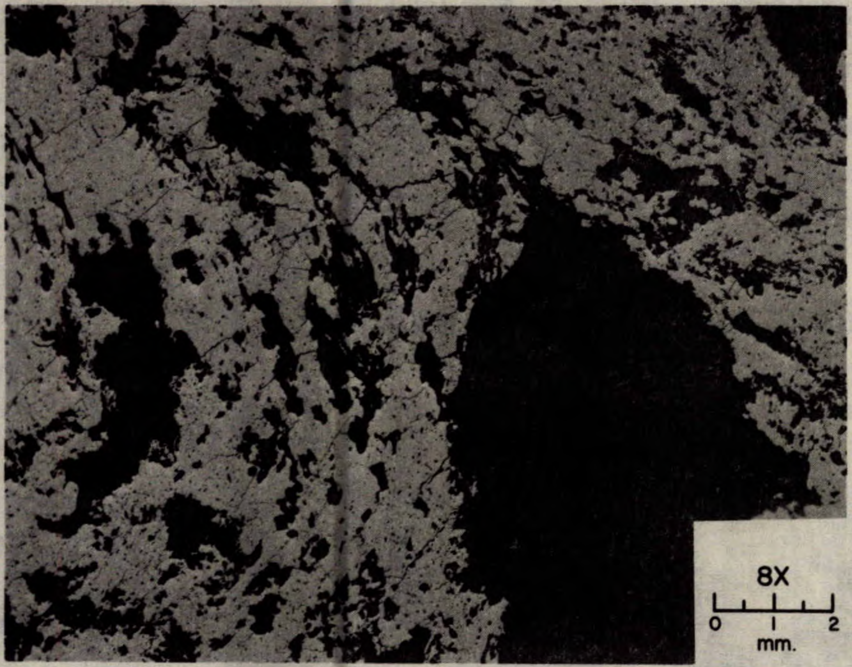

Figure 20. Photomicrograph of a polished section showing massive niccolite (white). The black area represents domomite.

(10) Disseminated Grains of Cobalt and Iron Arsenides in Calcite

Minute disseminated grains of arsenopyrite, cobaltite and skutterudite in calcite are present in a few veins. The arsenopyrite and cobaltite grains are very small, whereas the skutterudite grains are somewhat larger and are usually in the form of euhedral crystals. These minerals are usually present as aggregates of minute grains along calcite grain boundaries, and sometimes surround calcite crystals (Figure 21); this indicates that the arsenides have been introduced along grain boundaries and replaced calcite. The author suggests that these aggregates are the incipient forms of the rosettes and that the trapped calcite crystals are incipient cores of the rosettes.

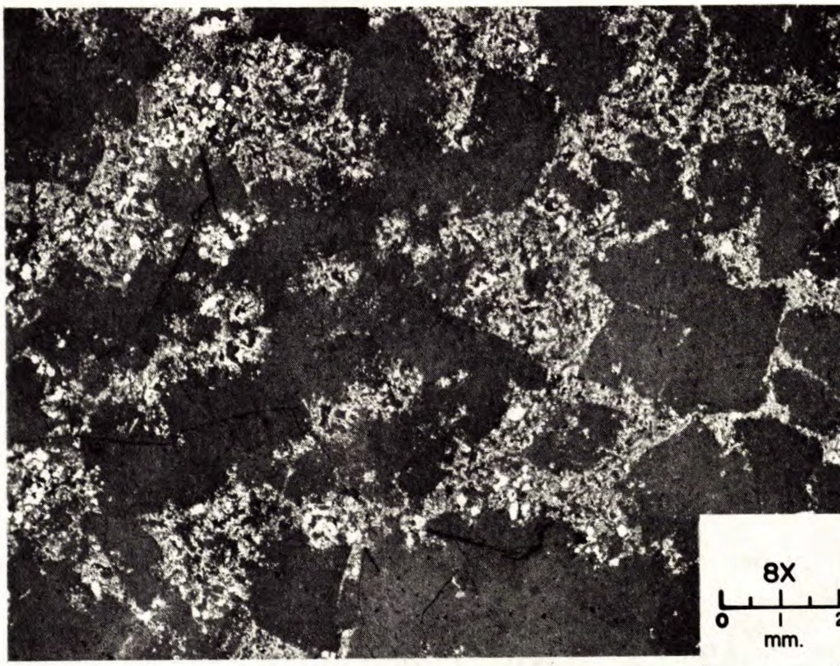

Figure 21. Photomicrograph of a polished section of vein 37 in the Iangis mine, showing minute disseminated grains of cobaltite and arsenopyrite (light grey grains) and slightly larger skutterudite grains (white). The grey area represents calcite.

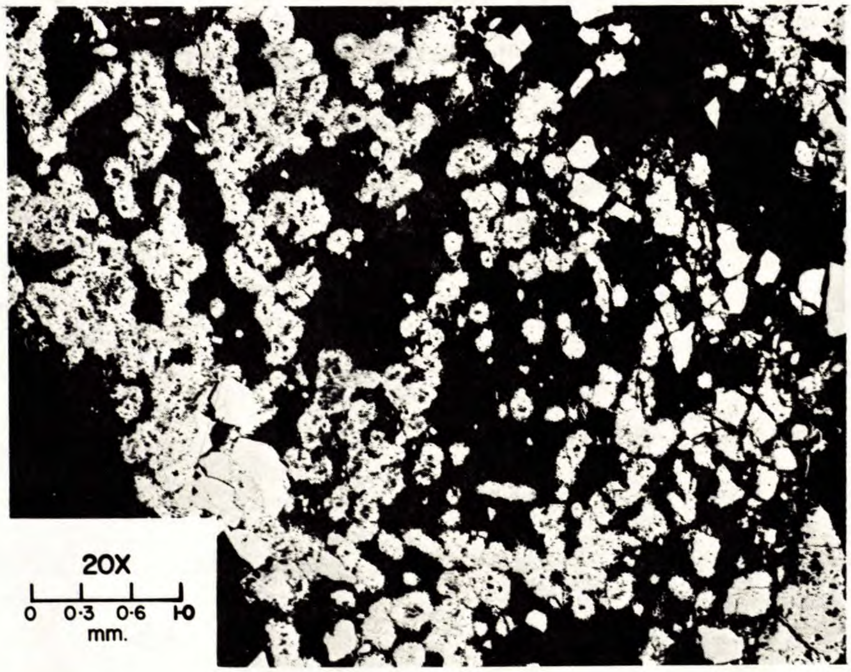

Figure 22. Photomicrograph of a polished section of vein 21 in the Hi-Ho mine, showing euhedral crystals of arsenopyrite (white) and rounded bodies of arsenides (white) in carbonate (black). The rounded bodies consist of skutterudite intergrown with cobaltite.

(11) Disseminated Grains, Masses and Veinlets of Arsenides, Silver-Sulphantimonides, Native Silver and Sulphides in Carbonate

Veins containing disseminated grains, masses and veinlets of arsenides, silver-sulphantimonides, native silver and sulphides in carbonate are mineralogically similar to the terminal parts of high-grade veins. They usually contain masses and disseminated grains of cobaltite, arsenopyrite, skutterudite, niccolite, safflorite, breithauptite, pyrargyrite and native silver, and veinlets of chalcopyrite, tetrahedrite, pyrargyrite, sphalerite and galena (Figures 22 and 23). In the Hi-Ho mine, Vein 21, which occurs at the edge of an ore zone, has this type of mineralogy.

(12) Sulphide Veinlets in Calcite Veins

Calcite veins containing veinlets (Figure 24), masses and irregular grains of marcasite, galena, pyrite and chalcopyrite are present as narrow fault veins in most mines. The attitudes of the fault veins vary from vertical to horizontal. Many of the faults are post-ore faults and offset mineralized veins from a few inches to several feet.*

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* Personal communication with mine operators at Cobalt, Ontario.

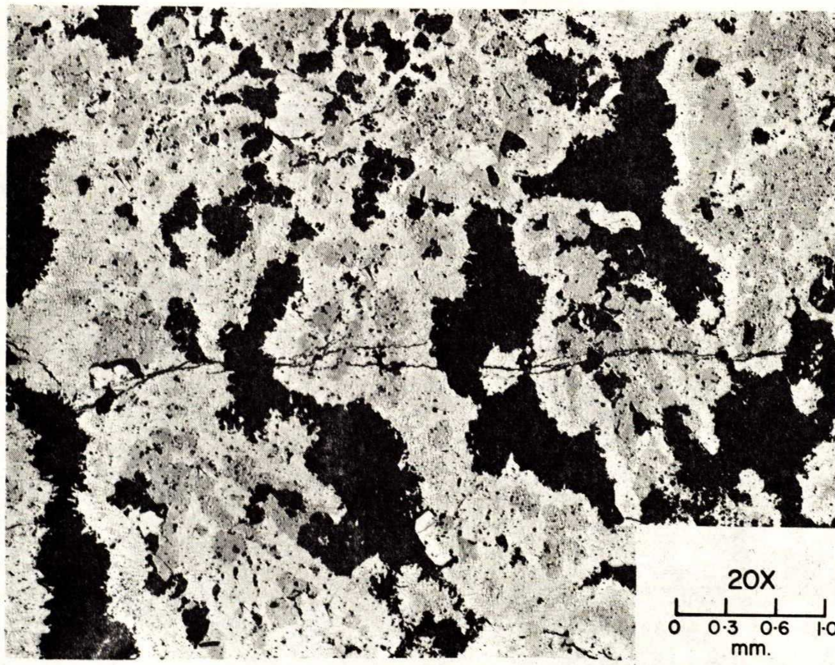

Figure 23. Photomicrograph of a polished section of vein 21 in the Hi-Ho mine, showing irregular masses of arsenides. They consist of niccolite (grey), and safflorite, cobaltite and skutterudite (white). The black area represents a carbonate mineral.

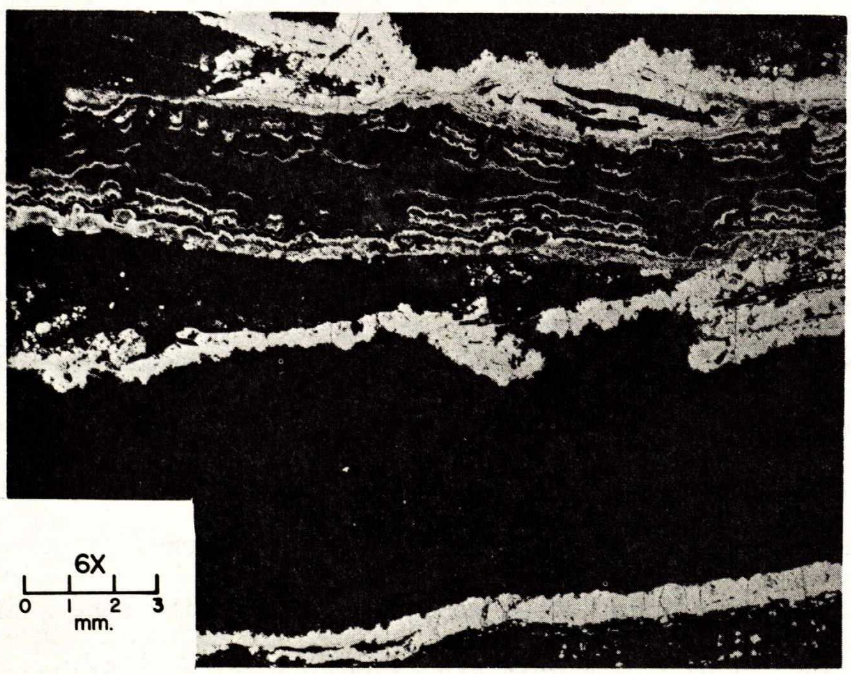

Figure 24. Photomicrograph of a polished section of a calcite vein in the Hi-Ho mine. The calcite contains numerous pyrite and marcasite veinlets (white).

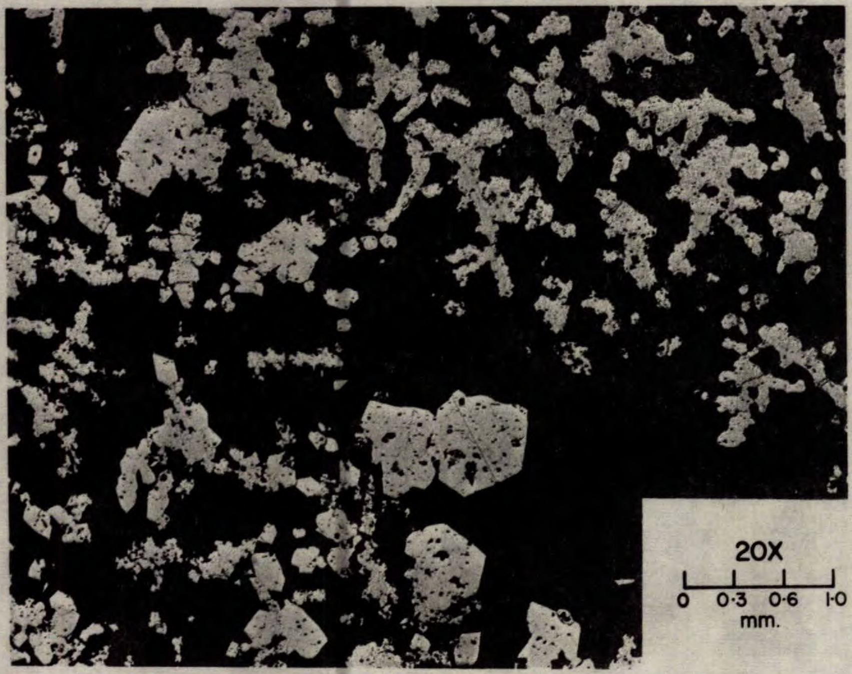

Figure 25. Photomicrograph of a polished section of the terminal portion of vein 504E in the Glen Lake mine. This section of the vein contains euhedral arsenopyrite crystals, and admixed bodies of skutterudite, safflorite and cobaltite. The black areas represent carbonate.

Ore Minerals in the Terminal Portions

The terminal portions of most veins contain an arsenopyrite zone, a sulphide zone, and a carbonate vein. The arsenopyrite zone adjoins the central portions of the veins. This zone extends for several tens of feet in some places and is absent in others. It consists of arsenopyrite, safflorite, skutterudite, native silver and sulphides in a carbonate matrix (Figures 25 and 26). The arsenopyrite occurs as irregular grains, euhedral crystals, and rosettes, disseminated in carbonate. The irregular grains are generally very small, and the euhedral crystals are comparatively large.

The sulphide zone lies beyond the arsenopyrite zone. It consists of irregular grains, masses and veinlets of chalcopyrite, tetrahedrite, sphalerite, galena, arsenopyrite, marcasite and pyrite, all in carbonate (Figure 27).

The carbonate vein extends beyond the sulphide zone and is largely

Figure 26. Photomicrograph of a polished section of the terminal portion of vein 15 in the Agnico-Christopher mine, showing safflorite rosettes and euhedral arsenopyrite crystals.

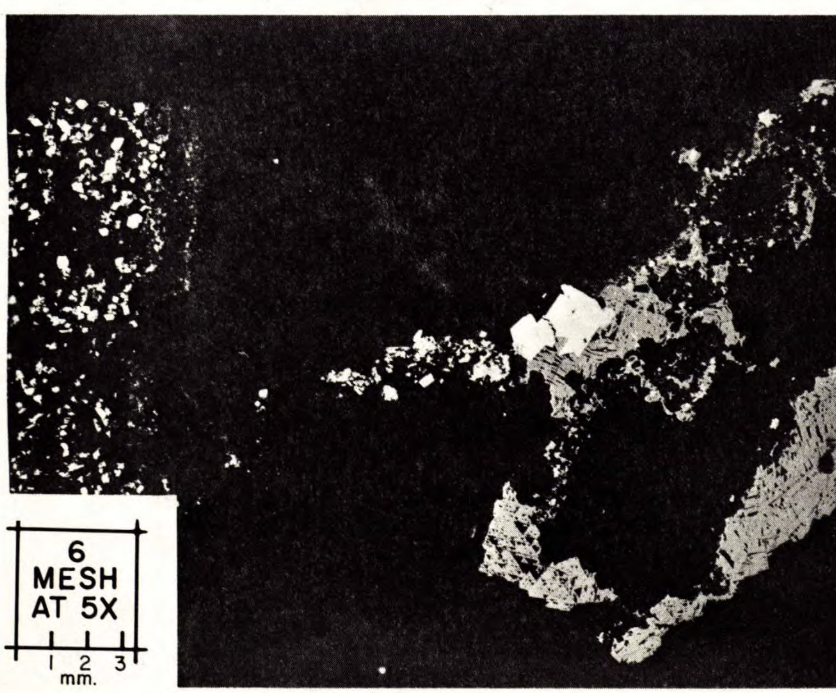

Figure 27. Photomicrograph of a polished section of the terminal portion of vein 504E in the Glen Lake mine. It shows masses of galena (grey) and crystals of arsenopyrite (white), in carbonate (dark grey).

barren of ore minerals. In some places it pinches out in a very short distance, while in other places it continues for several hundred feet. It consists of massive carbonate and contains a few disseminated grains of arsenopyrite, tetrahedrite, chalcopyrite, sphalerite, marcasite and galena. The disseminated grains are present as separate grains and as intergrowths of the various minerals.

Ore Minerals at the Margins of the Veins

Most veins contain disseminations of sulphide minerals at the margins and are bordered by sulphide and chlorite veinlets. The sulphide minerals at the margins are most abundant near the terminal portions of the veins and occur as disseminated grains in arsenides and carbonates. These minerals are pyrargyrite, stephanite, acanthite, tetrahedrite, chalcopyrite, pyrite, marcasite, sphalerite, violarite, galena, arsenopyrite, sphene, native bismuth, and bismuthinite. It is noted that silver-bearing sulphides are present at the edges of silver-bearing veinlets and bismuth minerals are present at the edges of silver-deficient veins.

Sulphide veinlets are present in a few places as borders on the veins, and are generally separated from the main vein by narrow chlorite veinlets (Figure 28). They vary from about 1 to 10 millimetres in width and consist of parallel sub-veinlets of sphalerite, marcasite, galena and stephanite in calcite (Figure 29). They also contain irregular grains of chalcopyrite, pyrite, pyrrhotite, pyrargyrite and molybdenite.

Carbonate Minerals Forming the Matrix of the Veins

Dolomite, calcite and siderite* form the matrix of the mineralized veins. Dolomite is the main constituent of the mineralized veins in the Cobalt

* The various carbonates were differentiated according to the method outlined by Warne (see Appendix II), and by X-ray diffraction.

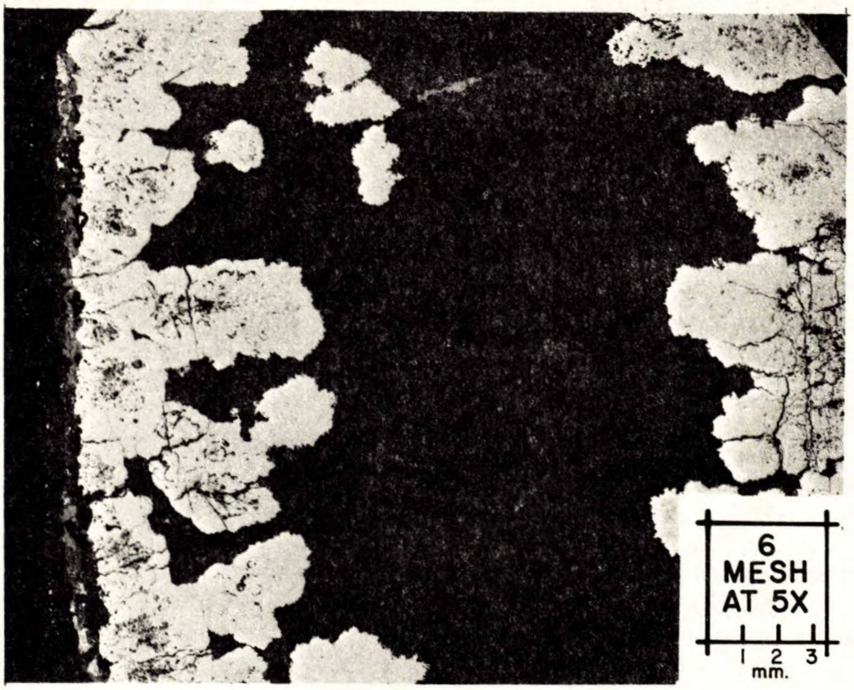

Figure 28. Photomicrograph of a polished section of a vein in F-8N drift in the Hi-Ho mine. This vein consists of carbonate at the centre (black), rosettes and masses of arsenides at the margins (white), and a narrow sulphide veinlet along the left edge (grey).

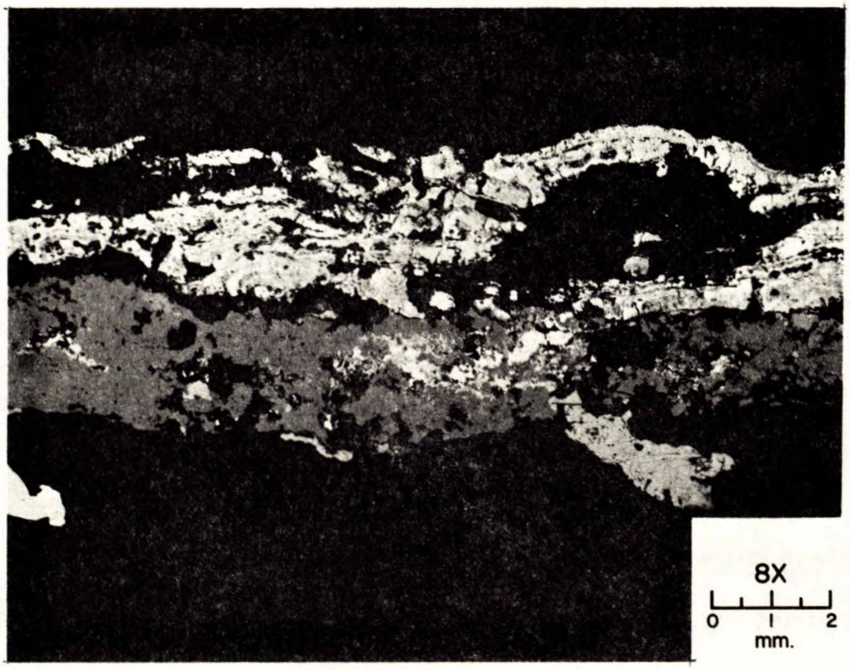

Figure 29. Photomicrograph of a polished section showing a sulphide veinlet from the border of a vein, and a layer of chlorite along the bottom of it (black). The sulphide veinlet consists of sub-veinlets of marcasite (white) and sphalerite (grey). A mass of stephanite (light grey) extends from the sphalerite into the chlorite.

area, whereas calcite is the main constituent of the mineralized veins in the Gowganda area mine of Siscoe Metals of Ontario (2). X-ray diffraction studies show that the calcite:dolomite ratio in the Patricia vein of the Hi-Ho mine varies from about 0.04 to 0.35 in the mineralized section, and is about 1.6 about 50 feet west of the mineralized section.

The dolomite occurs as masses of white to light grey crystals, and contains large euhedral crystals and minute grains of calcite. Semi-quantitative spectrochemical analyses of dolomite from some mineralized veins in the Cobalt area are given in Table 3. The results show that the dolomite contains a variety of trace elements. The quantity of silver in it appears to be related to the proximity of the samples to an ore zone. The copper content, on the other hand, is unrelated to the proximity of samples to an ore zone and appears to be anomalously high. It is possible that dolomite from mineralized veins is enriched in copper.

Calcite is the main constituent in one of the silver-bearing veins (vein 470, Agnico-Christopher mine), in one of the silver-deficient veins (vein 37 Langis mine), in the late fault veins, and in sulphide veinlets at the borders of mineralized veins. The calcite in the silver-bearing vein is colourless to dark grey and is present as minute grains and large euhedral crystals. That in the silver-deficient vein is colourless to white in hand specimens and is largely present as euhedral crystals. The calcite in the fault veins is white and some of it has a sugary texture.

Siderite is the main constituent in the mineralized sections of vein 30 in the Langis mine and vein 407 in the Agnico-Christopher mine. The siderite is reddish-brown to black in hand specimens. That in the Langis mine occurs as irregular masses, while that in the Agnico-Christopher mine occurs as nodules.

TABLE 3

Semi-Quantitative Spectrographic Analyses* of Dolomite from Cobalt

Sample No.	Mine	Vein	Zone	Mg	Al	Si	Ca	V	Mn	Fe	Cu	Ag	Pb	Bi
2	Hi-Ho	Patricia	ore	PC	0.05	0.4	PC	0.002	1.5	5.4	0.07	0.001	ND	0.001
3	Hi-Ho	Patricia	ore	PC	0.04	0.4	PC	0.001	1.0	0.8	0.05	0.07	0.04	tr
13	Hi-Ho	Patricia	ore	PC	0.003	0.02	PC	tr	1.0	0.8	0.03	0.01	0.04	0.006
8	Hi-Ho	Patricia	barren	PC	0.02	0.6	PC	tr	0.1	0.5	0.05	tr	ND	ND
15	Hi-Ho	21	ore	PC	ND	0.02	PC	tr	0.6	0.7	0.04	0.02	ND	ND
16	Hi-Ho	Cadesky	ore	PC	0.002	0.03	PC	ND	0.2	0.7	0.02	0.01	ND	ND
28	Deer Horn	506	ore	PC	0.002	0.03	PC	ND	0.1	0.1	0.03	0.01	ND	ND

* Internal Report SL-65-047, Analytical Chemistry Sub-Division, Mineral Sciences Division, Mines Branch, by J. L. Dalton (1965).

DISCUSSIONS AND TENTATIVE CONCLUSIONS

This preliminary study suggests that it may be possible to utilize certain mineralogical features in the exploration for silver in the Cobalt area. The principal one is that arsenopyrite and sulphide minerals occur at the terminal portions and edges of the ore veins, and in small veins at the edges of groups of veins. This relationship suggests that arsenopyrite-sulphide mineralization could indicate an edge of a mineralized zone.

The variety of carbonates in the vein may also be indicative of an ore zone. Siderite appears to contain disseminated silver-sulphantimonides, and dolomite appears to be the predominant mineral in mineralized veins containing arsenides and silver. In addition, it is suggested that trace amounts of copper in dolomite may be indicative of mineralization.

It is noted that all the mineralized veins contain significant amounts of arsenic- and copper-bearing minerals. This suggests that geochemical anomalies of arsenic and copper can be expected around the mineralized veins. Dr. R. W. Boyle of the Geochemistry Section of the Geological Survey of Canada has indicated that he plans to have this investigated shortly (personal communication).

ACKNOWLEDGEMENTS

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X-ray diffraction, P. O'Donovan and A. Harrington for preparing polished sections, and D. R. Owens for preparing the photomicrographs.

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2. S. D. Scott, "Silver Mineralization in Number 13 Vein System, Siscoe Metals of Ontario, Gowganda", M.Sc. Thesis, University of Western Ontario, London, Canada (1964).
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APPENDIX I

CHEMICAL COMPOSITIONS OF MINERALS REFERRED TO IN REPORT

Acanthite	Ag_2S	Niccolite	$NiAs$
Arsenopyrite	$FeAsS$	Pararammelsbergite	$NiAs_2$
Bismuthinite	Bi_2S_3	Pyrargyrite	Ag_3SbS_3
Breithauptite	$NiSb$	Pyrite	FeS_2
Calcite	$CaCO_3$	Pyrrhotite	$Fe_{1-x}S$
Chalcopyrite	$CuFeS_2$	Rammelsbergite	$NiAs_2$
Cobaltite	$CoAsS$	Safflorite	$CoAs_2$
Dolomite	$CaMg(CO_3)_2$	Siderite	$FeCO_3$
Dyscrasite	Ag_3Sb	Skutterudite	$CoAs_3$
Galena	PbS	Skutterudite group	$(Co,Fe,Ni)As_3$
Gersdorffite	$NiAsS$	Sphalerite	ZnS
Glaucodot	$(Co,Fe)AsS$	Sphene	$CaTiSiO_5$
Loellingite	$FeAs_2$	Stephanite	Ag_5SbS_4
Marcasite	FeS_2	Tetrahedrite	$(Cu,Ag,Fe)_{12}Sb_4S_{13}$
Molybdenite	MoS_2	Ullmannite	$NiSbS$
Native bismuth	Bi	Violarite	$FeNi_2S_4$
Native silver	Ag	Xanthoconite	Ag_3AsS_3

APPENDIX II

METHOD OF STAINING CARBONATES

The dolomite, calcite and siderite can be readily differentiated by staining with Alizarin red S according to the method described by Warne (3). According to this method, the sample is prepared for staining by etching with dilute hydrochloric acid (8 to 10 ml of commercial-grade hydrochloric acid in 100 ml of distilled water). If the specimen effervesces briskly in cold solution, it should be allowed to react for about three minutes. If it does not react in cold solution it should be etched in hot dilute hydrochloric acid for about thirty seconds. The mineral under test is then covered with Alizarin red S solution (0.1 gram Alizarin red S in 100 ml of 0.2 per cent cold hydrochloric acid) and allowed to react for about five minutes. The solution is then poured off and washed carefully by decantation. Calcite, witherite, high-magnesium calcite, and argonite are stained a deep red. Ankerite, ferroan dolomite, strontianite, and cerussite are stained purple, while anhydrite, siderite, dolomite, rhodocrosite, magnesite, smithsonite and gypsum are not stained at all.

The unstained specimens and those that stain purple can be further differentiated by boiling for five minutes in a solution composed of equal volumes of Alizarin red S solution and thirty per cent sodium hydroxide. Anhydrite and cerussite are unstained, siderite stains dark brown to black, ferroan dolomite dark reddish-brown, and dolomite, rhodocrosite, magnesite, ankerite, gypsum and smithsonite are stained purple. Further differentiation is obtained by boiling for five minutes in a liquid composed of equal volumes of Alizarin red S and five per cent sodium hydroxide solutions. Dolomite and rhodocrosite remain unstained, whereas magnesite, gypsum and smithsonite stain purple.

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