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REPORT

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STUDY OF THE PB, ZN, FE, CU, AG, HG, MN AND BA OCCURRENCE AND DISTRIBUTION IN 12 SAMPLES OF METALLURGICAL PRODUCTS FROM THE YUKON TERRITORY

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Report no. 420

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August 15 1984

Prepared for:

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INTRODUCTION

A mineralogical study was conducted on 12 samples of metallurgical products from the Cyprus Anvil Pb-Zn-Ag mine in the Yukon Territory. The products consisted of 4 sets each including a lead concentrate, a zinc concentrate and tailings originated from the top, middle and bottom of the deposit. Purpose of the study was to:

- Describe the grain size, degree of liberation and association of the economic minerals;
- Identify the Pb, Zn, Fe, Cu and Ag-bearing minerals in all the products;
- Locate and identify the Hg-bearing minerals in the zinc concentrates;
- Locate and identify the Mn and Ba-bearing minerals in the lead and zinc concentrates;
- Identify the gangue (contaminating) minerals in the lead and zinc concentrates.

Brief descriptions of the 4 ore types, provided by Mr. Brian Arsenault in a letter dated May 1 1984, are as follows:

2A-36533 - Sulfide-bearing, ribbon-banded, graphitic quartzite.

Low S.G. - approximately 3.1. Typical assay: 2.0% Pb, 4.0% Zn, 10-18% Fe.

The low bulk density of the ore and low grindability of the quartzite reduce throughput. The hydrophobic graphite reduces cleaner performance, lowering lead concentrate grade. Zinc metallurgy with this ore type is usually fair to good. This ore type can display exceptional metallurgy in rare cases when graphite content is low and the lead and zinc content is high in the heads. The zone 3 ore body has a much lower percentage of 2A material, 9% versus 30% in zone 2.

2BCD-26534 - Combination of ore types 2B, 2C and 2D. This ore type is similar to 2A, but contains much less graphite.

S.G. approximately 3.3. Typical assay: 3.0% Pb, 5.0% Zn, 16-20% Fe.

Low grindability of the quartzitic component coupled with the low bulk density restricts throughput. Metallurgically the ore is a good performer. Both lead and zinc grades and recoveries are good to excellent. Zone 3 contains about 20% BCD material versus only 9.5% in Zone 2.

2EF-36535 - Massive pyritic sulfides, buckshot facies.

S.G. 4.0-4.5. Typical assay: 3.0% Pb, 5.0% Zn, 30-35% Fe.

No problems with throughput. Metallurgy is good to excellent. Much higher cyanide requirements than the lower iron rock types. 2EF rock type makes up 44% of the Zone 3 ore body compared to 10% of the zone 2 material.

2H-26536 - Pyrrhotitic facies, massive sulfides.

S.G. 4.0-4.5. Typical assay: 3.5% Pb, 5.0% Zn, 35-40% Fe.

The high pyrrhotite content of this ore type results in very poor metallurgy. Consumption on all reagents should be very high. Recoveries could be as low as 50% on both lead and zinc at grades of 50% for both lead and zinc. 2H ore constitutes 6% of the ore in Zone 3 as opposed to no 2H in Zone 2.

Chemical analyses, provided by Mr Arsenault in the same letter are:

ORE TYPE	PRODUCT	Pb %	Zn %	Fe %	Cu%	Ag gMT	no. of polished mounts
2A	Lead rougher conc.	13.00	3.89	4.20	0.30	198.1	2
2A	Zinc rougher conc.	1.18	30.40	8.50	0.17	37.6	3
2A	Tailings	0.34	0.22	3.60	0.03	9.6	4
2BCD	Lead rougher conc.	39.50	9.25	10.30	1.03	580.7	2
2BCD	Zinc rougher conc.	0.63	40.30	11.90	0.26	46.3	3
2BCD	Tailings	0.36	0.47	14.80	0.04	26.8	3
2EF	Lead rougher conc.	42.80	7.68	17.10	0.30	399.1	2
2EF	Zinc rougher conc.	0.93	43.40	15.10	0.25	33.6	3
2EF	Tailings	0.54	1.07	37.90	0.09	16.5	4
2H	Lead rougher conc.	36.10	10.37	20.30	1.29	408.7	2
2H	Zinc rougher conc.	0.91	44.30	16.20	1.17	30.8	3
2H	Tailings	0.55	0.63	42.50	0.14	32.0	3

Approximate analyses for mercury, manganese and barium, provided by Mr. Arsenault during a telephone conversation are: Hg 100 to 600 ppm in the zinc concentrates and 20 to 60 ppm in the lead concentrates, Mn 0.5 to 1% in the zinc concentrates and 0.03 to 0.3% in the lead concentrates and Ba 0.2%.

METHOD OF STUDY

The study was conducted as follows:

- A total of 34 polished mounts 1½" in diameter was prepared of the 12 samples. The number of mounts per sample was decided based on its silver content and is shown in the table on the previous page;

- One polished mount from each sample was examined by using reflected light microscopy and magnifications of 200x and 500x. All the common minerals were identified. Grain sizes, associations and approximate percentages were determined or estimated. Photomicrographs were taken;

- The entire surface of each of the 34 mounts was systematically scanned by using reflected light microscopy and magnifications of 500x and 1250x. Any grains with the optical properties of the Ag, Hg, Mn and Ba-bearing minerals, as well as particles of unidentified minerals were photographed and marked for SEM study;

- The grains marked during the microscope examination were magnified in the SEM up to 20,000 times, depending on their size and analyzed qualitatively by a solid state detector for energy-dispersive analysis attached to the instrument. The study involved the collection of x-ray spectra showing peaks at the energy positions of all the elements present in the analyzed microareas in amounts greater than approximately 0.5% and gave: (i) the composition of the particles and (ii) most identifications based on optical properties and chemistry together;

- Because no Hg, Mn or Ba-bearing minerals were found at the end of this study, a search for the 3 elements was conducted by (i) positioning markers at the Hg, Mn and Ba emission energies on the computer monitor, (ii) collecting x-ray spectra from approximately 100 grains and (iii) recording/identifying any grains which showed peaks at those energies.

RESULTS

Lead. Predominant Pb-bearing mineral is *galena*. Some minor carbonates and sulfates could be present. No other sulfides or sulfosalts were identified. Galena occurs mostly in liberated grains and grains associated with the sphalerite in the lead concentrates, in grains generally associated with the sphalerite in the zinc concentrates and in fine grains less than 30 microns in size enclosed in or attached to sphalerite, pyrite, pyrrhotite and quartz, in the tailings.

Zinc. Predominant Zn-bearing mineral is *sphalerite*. Minor carbonates and sulfates could also be present. Sphalerite occurs generally in liberated grains and in grains associated with galena in the zinc and lead concentrates and in liberated grains and grains associated with pyrite, pyrrhotite and quartz in

the tailings. Only approximately 10 per cent of the particles show exsolutions of chalcopyrite, a few per cent show exsolutions of galena.

Selected sphalerite grains (approximately 50 in each sample) showed variable amounts of Fe between 5 and 15% and minor variable amounts of Mn between the limits of detection of the SEM-EDS (0.5% approximately) and 4 %. The highest number of Mn-bearing particles was found in the zinc concentrate from the 2H portion of the deposit with an abundance of 70%. Mn-bearing sphalerite is less common in the lead concentrates where it only accounts for 15 to 20% of the total sphalerite.

Iron. Fe-bearing minerals are pyrite, marcasite, pyrrhotite, chalcopyrite, sphalerite, arsenopyrite, iron oxides and iron carbonates. Particles of metallic iron, observed in some of the products, are very likely of artificial origin.

Pyrite occurs in different proportions in all the samples and shows a massive and spongy appearence, the spongy one being more abundant in the 2H set of products. The particles are often liberated and, when massive, may show fine inclusions of galena, sphalerite and chalcopyrite. They are sometimes attached to marcasite.

Marcasite occurs in small amounts, probably 5 to 10 per cent of the pyrite, in all the samples and is often associated with pyrite.

Pyrrhotite occurs in minor to trace amounts in all the samples and is abundant the the 2H set where it reaches values between 15 and 30 per cent. It forms liberated grains and grains associated with the pyrite.

Chalcopyrite occurs in particles which are liberated, enclosed in pyrite or exsolved from sphalerite. Composite chalcopyrite-sphalerite-galena grains were also observed. Chalcopyrite occurs always in minor amounts of 2 per cent and less and is the predominant Cu-bearing mineral.

Sphalerite contains variable amounts of iron as described above.

Arsenopyrite occurs in small amounts in some of the products, and appears to be present in all the zinc concentrates. It normally forms grains associated with other sulfides such as galena, sphalerite and pyrite.

Iron oxides and carbonates occur in minor or trace amounts in all the samples, but are more abundant in the 2H set where they appear to replace part of the quartz and muscovite as gangue minerals. They occur in liberated often composite grains. They contain variable amounts of manganese, between the limits of detection of the SEM-EDS and 10 per cent.

Copper. Copper is scarce in all the samples. Predominant Cu-bearing mineral is

chalcopyrite, described above.

Silver. Ag-bearing minerals found are *tetrahedrite*, $(Cu,Fe,Ag)_{12}Sb_4S_{13}$, and *tetrahedrite-tennantite*, $(Cu,Fe,Ag)_{12}(Sb,As)_4\ S_{13}$. Both these minerals are extremely rare and occur in very fine particles, 5 microns in diameter or less, generally associated with galena, chalcopyrite and sphalerite and enclosed in pyrite and sphalerite. Their silver content is in the 15 to 20% range.

Mercury. No discrete Hg-bearing minerals were found in any of the 12 samples.

Manganese. Mn-bearing minerals are *sphalerite, and iron oxides and carbonates*, described above.

Barium. Ba-bearing mineral is a mica very similar in general composition to *muscovite*. The mineral is relatively abundant in the lead concentrates (several percent) and rare or absent in the zinc concentrates and tailings. Like the manganese in the sphalerite, barium occurs in the mica in variable amounts estimated between the limits of detection of the SEM-EDS and 5%. No other Ba-bearing minerals were found.

A grain of *stannite*, Cu_2FeSnS_4, was identified in the 2EF lead concentrate associated with a galena particle.

Gangue minerals are *quartz, muscovite, Ba muscovite, iron oxides and carbonates*. Quartz and muscovite are abundant in the lead concentrates, while quartz alone predominates in the zinc concentrates and tailings. The iron oxides and carbonates appear to be more abundant in the 2H set and probably sulfide portion of the deposit. In addition, large blue grains the composition of which includes Ti and Cl were found in amounts of 1 to 2 per cent in the lead concentrates and in much smaller amounts in the other products. Their general appearence, chemical composition and their always liberated state, despite the large sizes, indicate an artificial origin. Silicates of aluminum are very minor. Titanium oxides were observed in minor to trace amounts in some of the tailings.

Grain sizes, mineral percentages by volume, and associations are shown in tables 1 to 12.

CONCLUSIONS

Conclusions drawn from the study are:

- Predominant Pb-bearing mineral is galena;
- Predominant Zn-bearing mineral is sphalerite;

- Fe-bearing minerals are pyrite, marcasite, pyrrhotite, chalcopyrite, sphalerite, arsenopyrite, iron oxides and carbonates;
- Predominant Cu-bearing mineral is chalcopyrite;
- The only Ag-bearing minerals found are tetrahedrite and members of the tetrahedrite-tennantite series. Because the total amount of these minerals occurring in the 12 samples is extremely scarce and does not account for the high silver values of the chemical assay, and because of the close Ag-Pb correlation shown by the chemical analyses, it is assumed that most of the element occurs in solid solution in the galena. An accurate microprobe analysis would confirm such statement, but, due to the difficulty in obtaining reliable values when dealing with low Ag concentrations in galena, the analysis is not recommended;
- Hg-bearing mineral is very likely sphalerite. Again a microprobe analysis would confirm such statement, but is not recommended for the reasons above;
- Mn-bearing minerals are some of the sphalerite and iron oxides and carbonates;
- Ba-bearing mineral is some of the muscovite;
- Gangue minerals are quartz, most abundant, muscovite with and without barium, iron oxides and carbonates and minor to very minor titanium oxides and alumino-silicates;
- The sphalerite in the lead concentrates is liberated and associated with galena;
- The galena in the zinc concentrates is generally associated with sphalerite. It is less often associated with pyrite or liberated;
- Lead mineral lost in the tailings is unliberated fine galena still enclosed in or attached to sphalerite, pyrite, pyrrhotite and quartz;
- Zinc mineral lost in the tailings is sphalerite occurring in liberated grains as well as in fine particles associated with pyrite, pyrrhotite and quartz;
- Silver minerals lost in the tailings are galena and fine tetrahedrite enclosed in pyrite.

TABLES

Shown on the following pages (8 to 19) are the mineralogical compositions of the 12 products, their approximate percentages by volume and the manner of occurrence of the individual minerals

PRODUCT: 2A-36533 - Lead concentrate

	%		g/MT
Pb	13.00	Ag	198.1
Zn	3.89		
Fe	4.20		
Cu	0.30		

Average size of particles: 30 to 60 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Gangue (quartz, muscovite, Ba muscovite)	70	Generally liberated. Some of the particles are attached to or enclose sulfides
Galena	16	Liberated, less often associated with sphalerite
Pyrite/marcasite (massive)	7	Generally liberated. Some of the particles are attached to or enclose other sulfides
Sphalerite (approximately 15% is Mn-bearing)	5	Generally liberated. Sometimes associated with galena, pyrite and gangue. 5 to 10 per cent of the particles show exsolutions of chalcopyrite
Chalcopyrite	1	Liberated and associated with pyrite and sphalerite
Pyrrhotite	tr	Associated with pyrite and liberated
Tetrahedrite-tennantite	tr	Only one grain was found totally enclosed in pyrite
Blue Ti-Cl grains	1	In large liberated grains

TABLE 1

PRODUCT: 2BCD-36534 - Lead concentrate

	%		g/MT
Pb	39.50	Ag	580.7
Zn	9.25		
Fe	10.30		
Cu	1.03		

Average size of particles: 5 to 50 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Galena	48	Liberated and attached to sphalerite. Less often associated with pyrite.
Sphalerite (Approximately 20% is Mn-bearing)	15	Liberated and attached to galena. Less often associated with pyrite and chalcopyrite
Pyrite/marcasite (spongy and massive)	14	Generally liberated. Some of the particles are attached to or enclose other sulfides.
Chalcopyrite	2	Often in large liberated particles. Also associated with pyrite and sphalerite
Pyrrhotite	tr	Liberated and with pyrite and chalcopyrite
Arsenopyrite	1	With galena and pyrite
Gangue (quartz, muscovite, Ba muscovite)	18	Generally in liberated grains. Also associated with sphalerite.
Blue Ti-Cl grains	2	In large liberated grains

TABLE 2

PRODUCT: 2EF-36535 - Lead concentrate

	%		g/MT
Pb	42.80	Ag	399.1
Zn	7.68		
Fe	17.10		
Cu	0.30		

Average size of particles: 5 to 60 microns.

Mineralogical composition	Approximate abundance %	Manner of occurrence
Galena	56	Liberated and associated with sphalerite and pyrite
Pyrite/marcasite (10-20% spongy)	25	Generally liberated. Some of the particles enclose other sulfides
Sphalerite (approximately 20% is Mn-bearing)	10	Liberated and associated with galena.
Chalcopyrite	1	Liberated and associated with pyrite. Occasionally exsolving from sphalerite
Pyrrhotite	1	Liberated and associated with pyrite
Iron oxides and carbonates (variable Mn)	2	In liberated sometimes composite grains
Tetrahedrite	tr	Only one grain was found enclosed in pyrite and associated with galena and chalcopyrite
Stannite	tr	Only one grain was found attached to galena
Gangue (quartz, muscovite, Ba muscovite)	5	Generally in liberated grains. Also associated with sphalerite and other sulfides

TABLE 3

PRODUCT: 2H-36536 - Lead concentrate

	%		g/MT
Pb	36.10	Ag	408.7
Zn	10.37		
Fe	20.30		
Cu	1.29		

Average size of particles: 5 to 60 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Galena	40	Liberated and associated with sphalerite
Sphalerite (approximately 20 % is Mn-bearing)	17	Liberated and associated with galena Occasionally associated with other sulfides
Pyrrhotite	25	Generally liberated. Sometimes associated with pyrite
Pyrite /marcasite (spongy and massive)	10	Liberated and associated with the other sulfides
Chalcopyrite	2	Liberated and associated with pyrite. Occasionally exsolving from sphalerite
Iron oxides and carbonates (variable Mn)	3	In liberated sometimes composite grains
Gangue (quartz and muscovite)	1	Liberated and attached to sulfides
Blue Ti-Cl grains	2	In large liberated grains

TABLE 4

PRODUCT: 2A-36533 - Zinc concentrate

	%		g/MT
Pb	1.18	Ag	37.6
Zn	30.40		
Fe	8.50		
Cu	0.17		

Average size of particles: 10 to 150 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Sphalerite (approximately 15% is Mn-bearing)	48	Generally liberated. Some of the particles show chalcopyrite and galena exsolutions
Galena	2	Liberated and associated with sphalerite
Pyrite /marcasite (some spongy. Mostly massive)	12	Liberated. Many of the particles show inclusions of other sulfides
Chalcopyrite	1	Liberated and associated with pyrite and sphalerite
Pyrrhotite	tr	Liberated and associated with pyrite and sphalerite
Arsenopyrite	2	Associated with other sulfides.
Gangue (predominantly quartz. Some muscovite and Ba muscovite)	35	Generally liberated. Some of the particles are attached to sulfides

TABLE 5

PRODUCT: 2BCD-36534 - Zinc concentrate

	%		g/MT
Pb	0.63	Ag	46.3
Zn	40.30		
Fe	11.90		
Cu	0.26		

Average size of particles: 5 to 60 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Sphalerite (approximately 50% is Mn-bearing)	60	Mostly in liberated grains. Sometimes attached to or enclosing/exsolving chalcopyrite and galena.
Galena	1	Generally with sphalerite, less often liberated and with pyrite.
Pyrite/marcasite (Some spongy. Mostly massive)	14	Generally liberated. Sometimes associated with other sulfides
Chalcopyrite	1	Liberated and with sphalerite. Less often with pyrite
Pyrrhotite	tr	Generally with pyrite
Arsenopyrite	1	Generally liberated
Tetrahdrite	tr	Only one grain was found associated with chalcopyrite and galena and enclosed in sphalerite
Gangue (predominantly quartz. Al-Si mineral. Very little muscovite)	23	Generally liberated. Some of the particles are attached to or enclose sulfides

TABLE 6

PRODUCT: 2EF-36535 - Zinc concentrate

	%		g/MT
Pb	0.93	Ag	33.6
Zn	43.40		
Fe	15.10		
Cu	0.25		

Average size of particles: 10 to 60 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Sphalerite (approximately 50% is Mn-bearing)	65	Mostly in liberated grains. Sometimes attached to or enclosing/exsolving chalcopyrite and galena
Galena	1	Generally associated with sphalerite and pyrite
Pyrite/marcasite (massive)	24	Liberated and associated with sphalerite
Chalcopyrite	1	Generally associated with sphalerite and pyrite
Pyrrhotite	1	With pyrite and liberated
Arsenopyrite	2	Generally associated with other sulfides
Tetrahedrite	tr	Only one grain was found associated with galena and enclosed in pyrite
Gangue (predominantly quartz. Very little muscovite)	6	Liberated and associated with sphalerite

TABLE 7

PRODUCT: 2H-36536 - Zinc concentrate

	%		g/MT
Pb	0.91	Ag	30.8
Zn	44.30		
Fe	16.20		
Cu	1.17		

Average size of particles: 5 to 50 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Sphalerite (approximately 70% is Mn-bearing)	67	Mostly in liberated grains. Sometimes associated with pyrite, pyrrhotite, galena and chalcopyrite
Galena	2	Generally associated with sphalerite
Pyrrhotite	15	Liberated and associated with sphalerite
Pyrite/marcasite (predominantly spongy)	10	Liberated and associated with sphalerite
Chalcopyrite	2	Liberated and associated with pyrite and sphalerite
Arsenopyrite	tr	Generally with other sulfides
Gangue (quartz)	2	Generally liberated
Fe oxides and carbonates (variable Mn)	2	In liberated sometimes composite grains
Blue Ti-Cl grains	tr	In large liberated grains

TABLE 8

PRODUCT: 2A-36533 - Tailings

	%		g/MT
Pb	0.34	Ag	9.6
Zn	0.22		
Fe	3.60		
Cu	0.03		

Average size of particles: 30 to 80 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Gangue (predominantly quartz. Some muscovite, very little Ba. Fe carbonates)	92	Generally liberated
Pyrite/marcasite (massive. Some spongy)	6	Generally liberated
Sphalerite	0.4	Liberated and associated with quartz and pyrite
Galena	0.8	Generally enclosed in pyrite, sphalerite and quartz
Chalcopyrite	0.8	Generally associated with pyrite and sphalerite

TABLE 9

PRODUCT: 2BCD-36534 - Tailings

	%		g/MT
Pb	0.36	Ag	26.8
Zn	0.47		
Fe	14.80		
Cu	0.04		

Average size of particles: 10 to 50 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Gangue (predominantly quartz. Some Fe carbonates. Rare muscovite)	72	Liberated
Pyrite/marcasite (spongy and massive)	25	Liberated
Sphalerite	0.7	Generally associated with gangue and liberated. Also associated with pyrite and galena
Galena	0.8	Associated with pyrite and sphalerite
Pyrrhotite	0.4	Generally with pyrite
Chalcopyrite	0.1	With pyrite and liberated
Ti oxides	1	Generally liberated

TABLE 10

PRODUCT: 2EF-36535 - Tailings

	%		g/MT
Pb	0.54	Ag	16.5
Zn	1.07		
Fe	37.90		
Cu	0.09		

Average size of particles: 10 to 50 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Pyrite/marcasite (massive. Occasionally spongy)	66	Generally liberated
Sphalerite	2	Often liberated. Also associated with pyrite
Galena	1	Generally attached to or enclosed in pyrite and sphalerite
Chalcopyrite	tr	Generally with pyrite and sphalerite. Also liberated
Fe oxides and carbonates (variable Mn)	1	Generally in liberated, sometimes composite grains
Gangue (predominantly quartz. Very little muscovite)	30	Liberated and associated with pyrite
Blue Ti-Cl grains	tr	In large liberated grains

TABLE 11

PRODUCT: 2H-36536 - Tailings

	%		g/MT
Pb	0.55	Ag	32.0
Zn	0.63		
Fe	42.50		
Cu	0.14		

Average size of particles: 10 to 50 microns

Mineralogical composition	Approximate abundance %	Manner of occurrence
Pyrite/marcasite (high % of spongy)	40	Generally liberated
Pyrrhotite	30	Generally liberated
Sphalerite	1	Generally attached to or enclosed in pyrrhotite. Less often associated with pyrite and gangue
Galena	1	Normally attached to or enclosed in pyrrhotite. Less often associated with pyrite and gangue
Chalcopyrite	tr	Liberated and associated with pyrite and gangue
Fe oxides and carbonates (variable Mn)	7	In liberated sometimes composite grains
Gangue (predominantly quartz)	20	Liberated and associated with fine sulfide
Blue Ti-Cl grains	1	In large liberated grains

TABLE 12

PLATES

Shown on the following pages are:

- Low magnification photomicrographs giving an indication of the average grain sizes and predominant minerals in the 12 products;

- High magnification photomicrographs showing Pb, Zn, Cu, Fe and Ag occurrences chosen as representative of the general mineralogy of the five elements;

- Photomicrographs of the stannite and of the blue Ti-Cl grains;

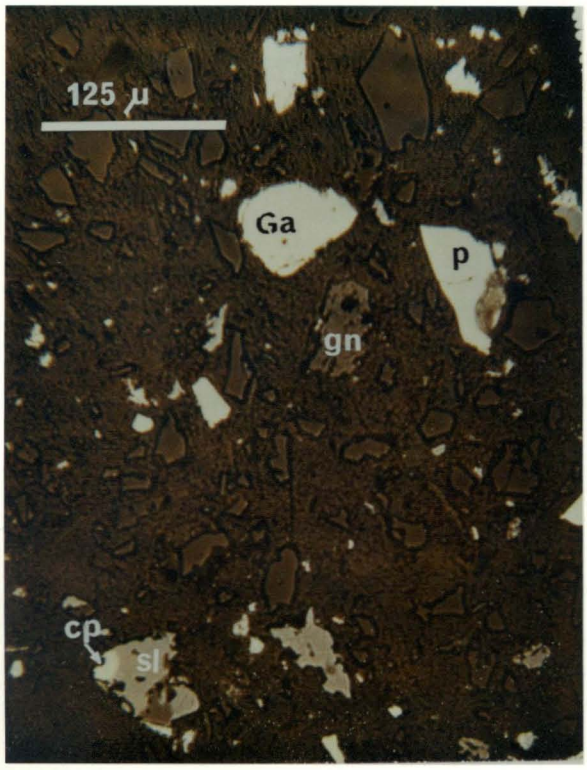
- SEM-EDS x-ray spectra showing the chemical compositions, including minor elements such as Mn and Ba, of most of the minerals described.

The photomicrographs were taken by using reflected light microscopy and magnifications of 200x, 500x and 1250x. The scales on some of the plates give an indication of the grain sizes.

LEAD CONCENTRATE

Sample 2A: particles of galena (Ga), pyrite (p), chalcopyrite (cp), sphalerite (sl) and gangue (gn) photographed by using magnifications of 200x (top two photomicrographs) and 1250x (bottom two photomicrographs).

Most of the particles are liberated, the chalcopyrite however is attached to or exsolved from the sphalerite.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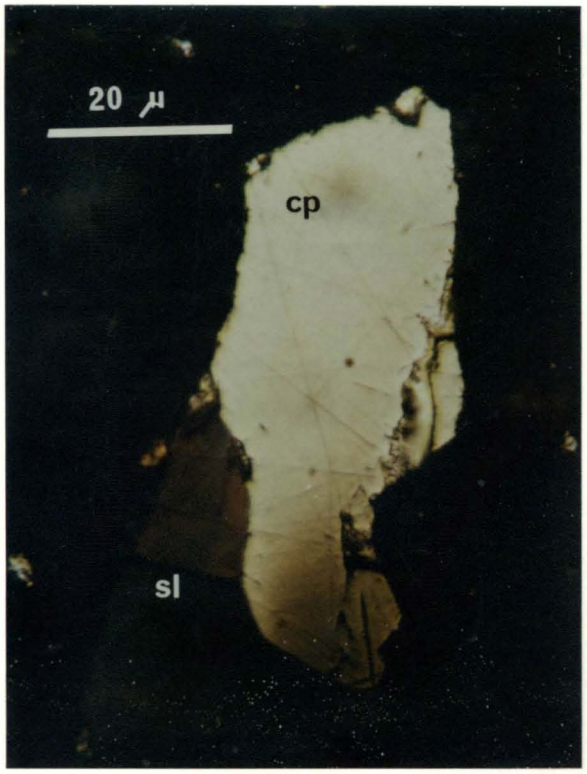
Ga
p
gn
cp
sl


sl
Ga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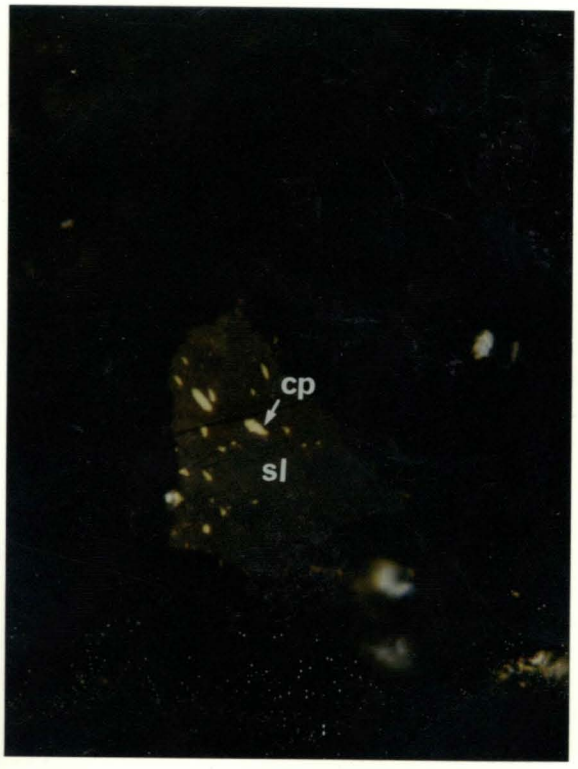
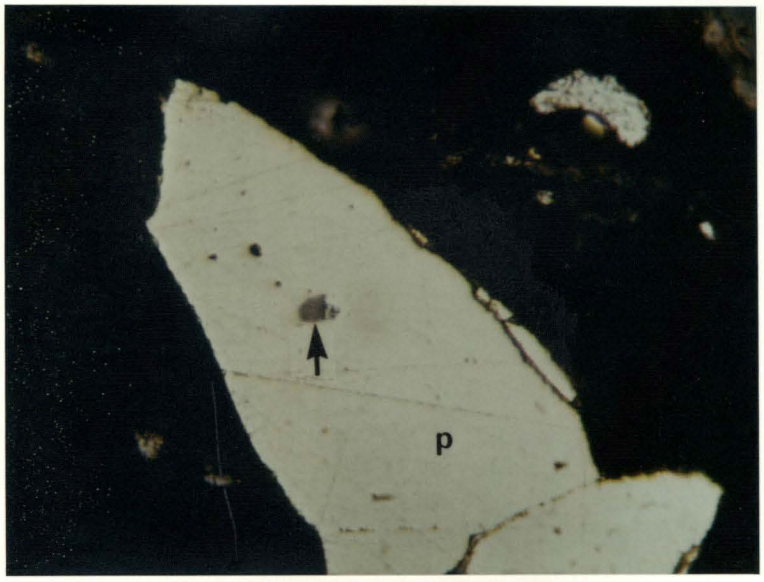
cp
sl


cp
sl

LEAD CONCENTRATE

Sample 2A: a very fine particle of tetrahedrite-tennantite (marked by arrow) enclosed in pyrite

Magnification: 1250x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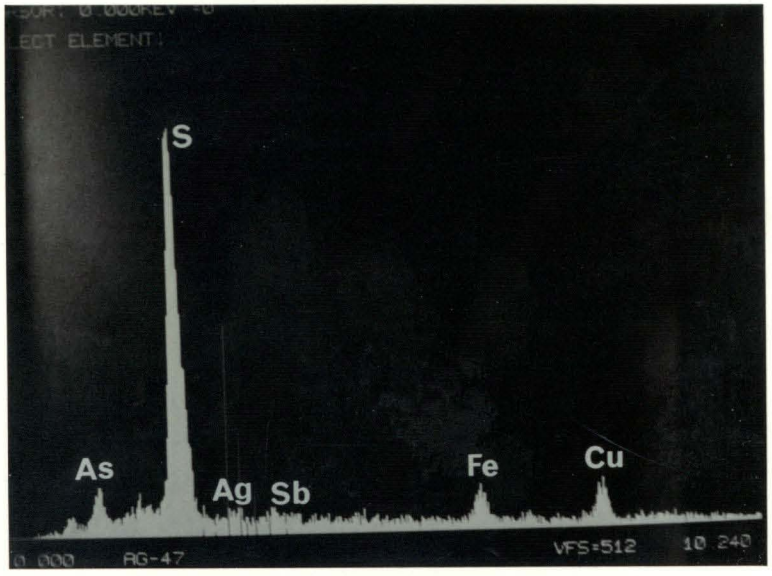
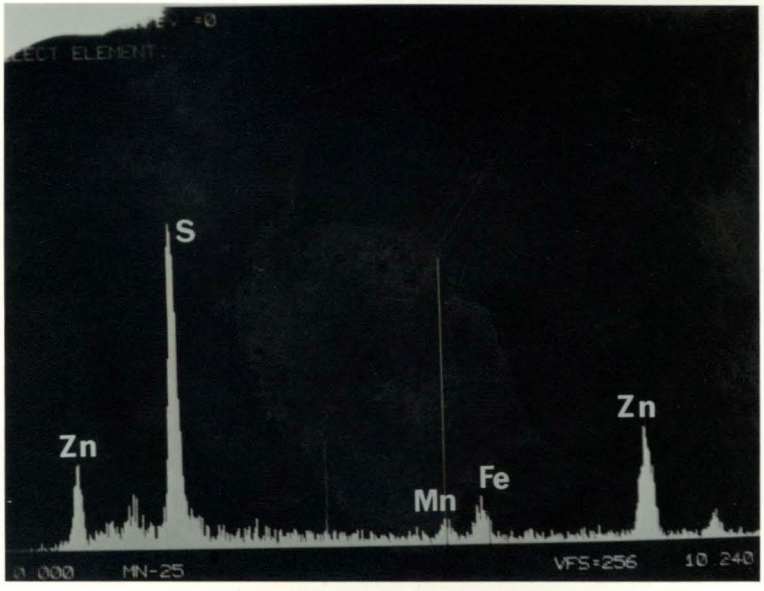
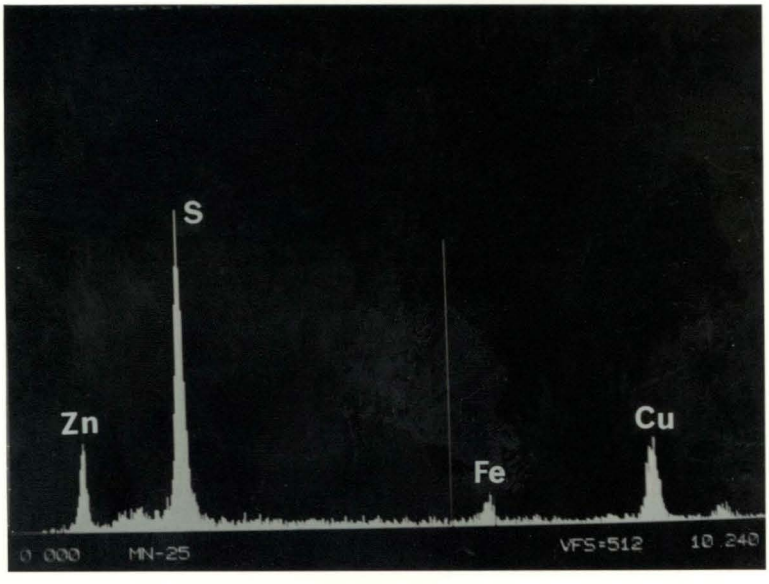

S
As
Ag
Sb
Fe
Cu
AG-47
VFS=512
10 240

LEAD CONCENTRATE

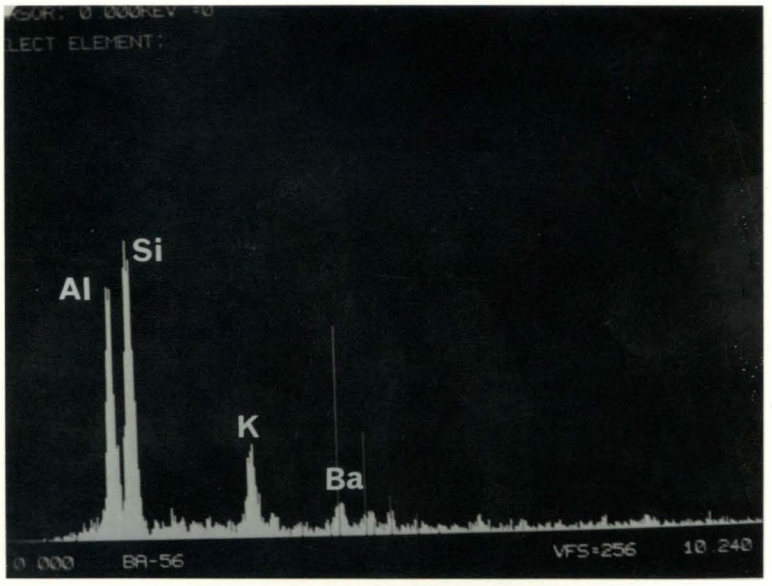
Sample 2A: x-ray spectra of two sphalerite grains showing markers at the Mn emission energy position. The top spectrum shows minor amounts of Mn, while the bottom one shows no Mn above the limits of detection of the SEM-EDS

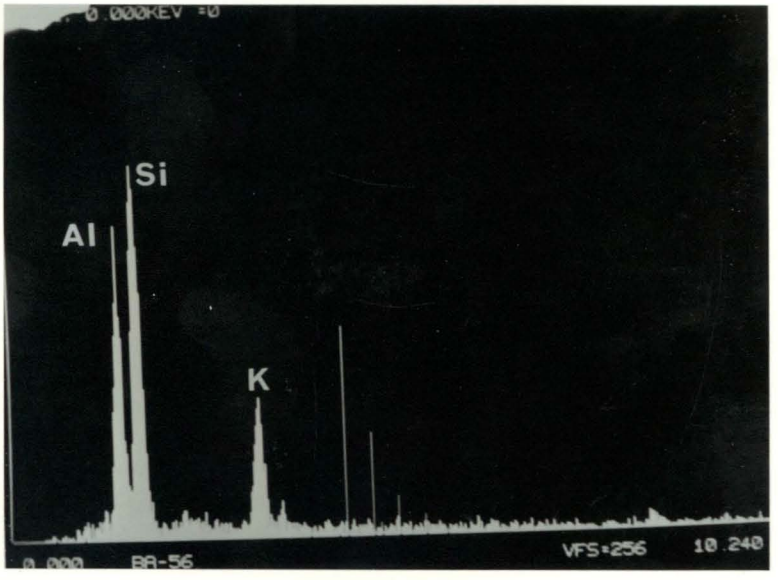

S
Zn
Zn
Mn
Fe
0.000
MN-25
VFS=256
10.240


S
Zn
Fe
Cu
0.000
MN-25
VFS=512
10.240

LEAD CONCENTRATE

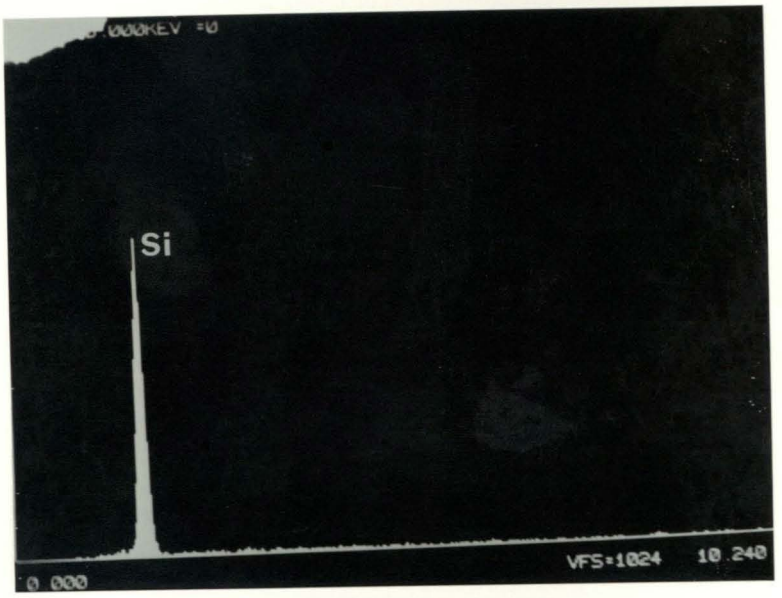
Sample 2A: x-ray spectra of two muscovite grains showing markers at the Ba emission energy position. The top spectrum shows minor amounts of Ba, while the bottom one shows no Ba above the limits of detection of the SEM-EDS


LECT ELEMENT:
Si
Al
K
Ba
0.000
BA-56
VFS=256
10.240


0.000KEV =0
Si
Al
K
0.000
BA-56
VFS=256
10.240

LEAD CONCENTRATE

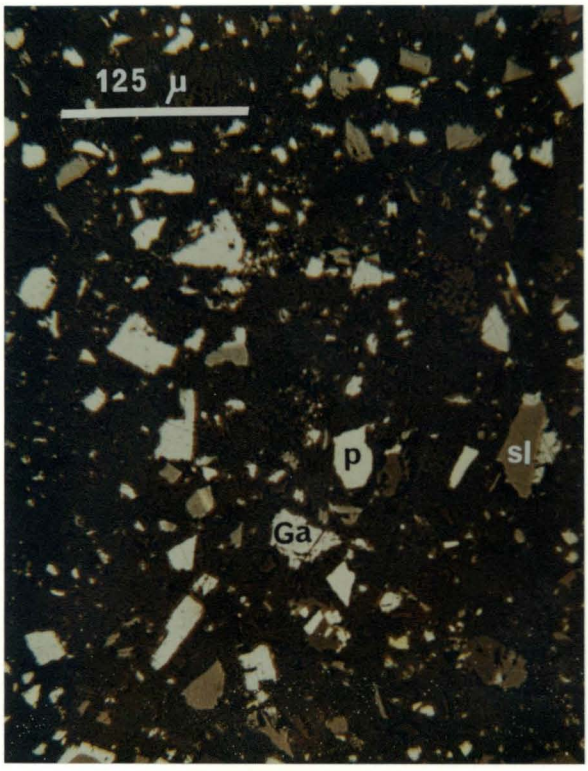
Sample 2A: x-ray spectrum of quartz

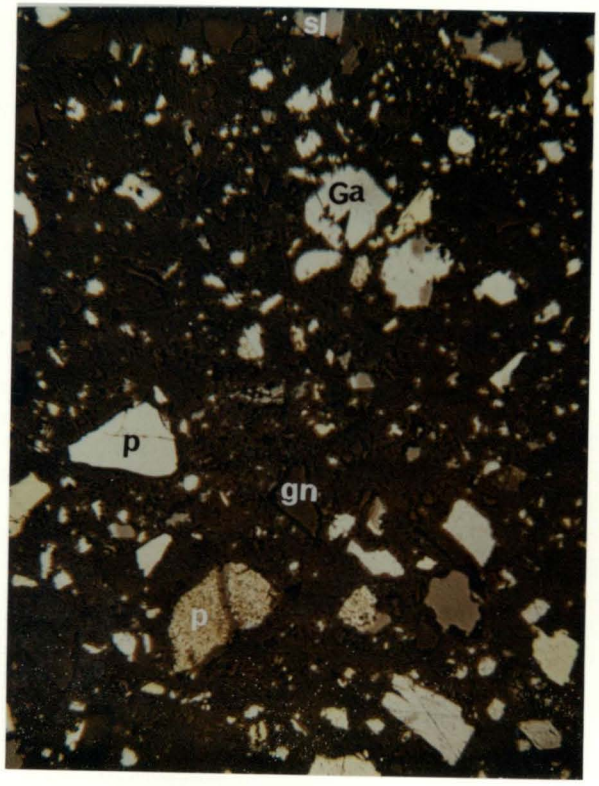

.000KEV =0
Si
0.000
VFS=1024
10.240

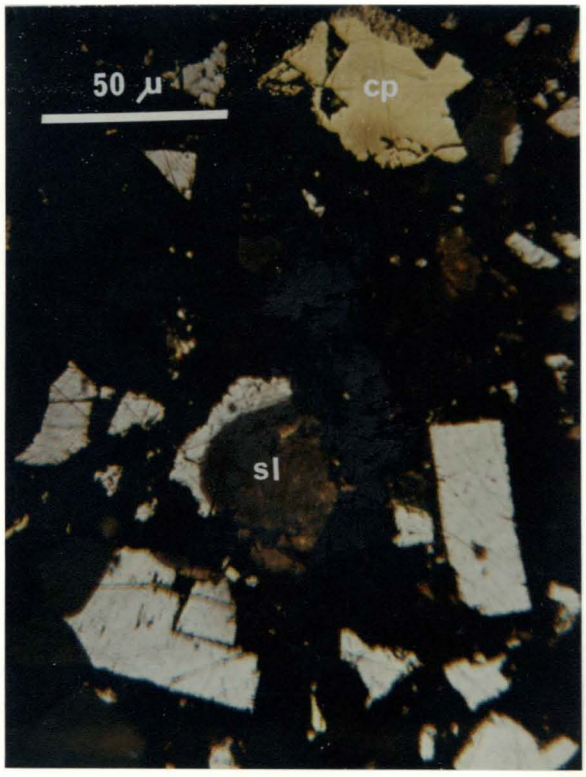
LEAD CONCENTRATE

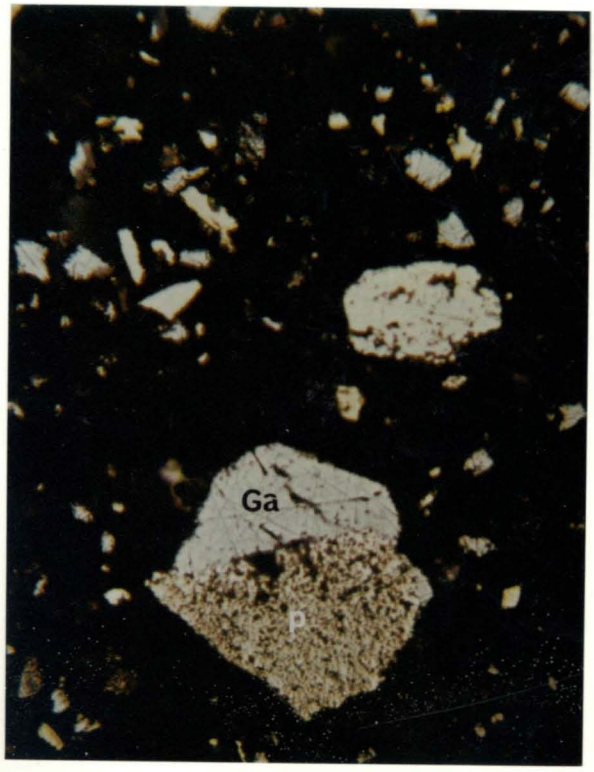
Sample 2BCD: particles of galena, sphalerite, pyrite, chalcopyrite and minor gangue photographed by using magnifications of 200x (top two photomicrographs) and 500x (bottom two photomicrographs).

The pyrite shows spongy and massive appearence. The chalcopyrite is large and liberated. The sphalerite is associated with galena.


125 µ
p
sl
Ga


sl
Ga
p
gn
p

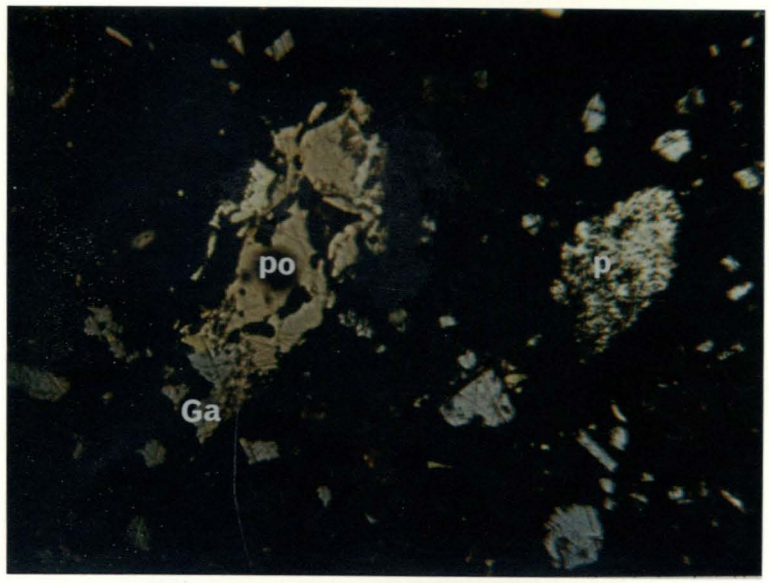

50 µ
cp
sl

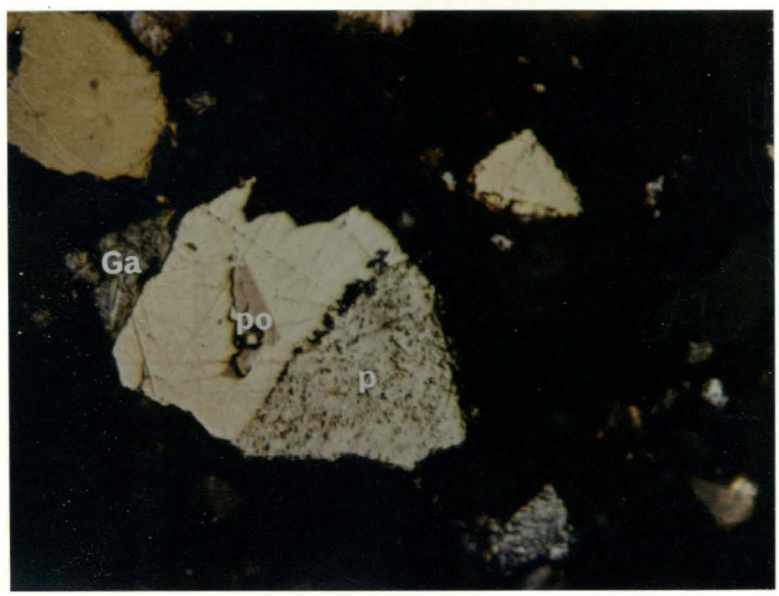

Ga
p

LEAD CONCENTRATE

Sample 2BCD: particles of pyrrhotite (po), galena and pyrite showing different associations. The pyrite is spongy and massive

Magnifications: 500x for the top photomicrograph and 1250x for the bottom photomicrograph


po
p
Ga

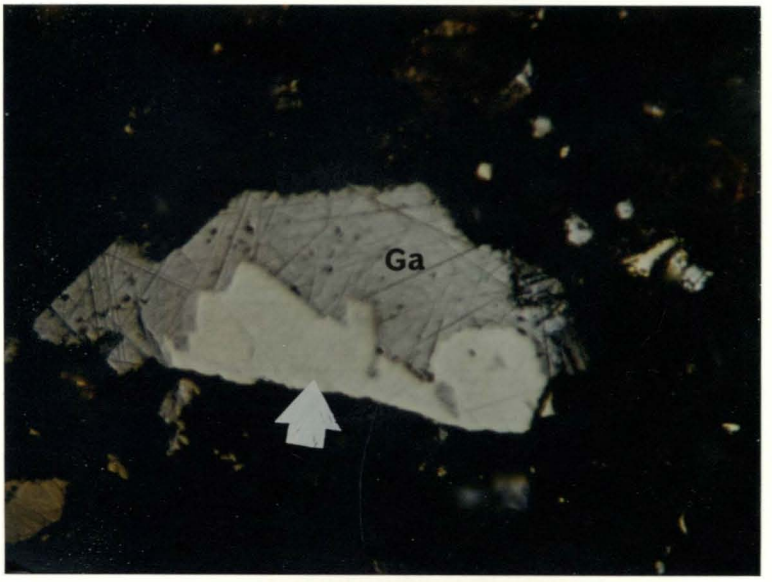

Ga
po
p

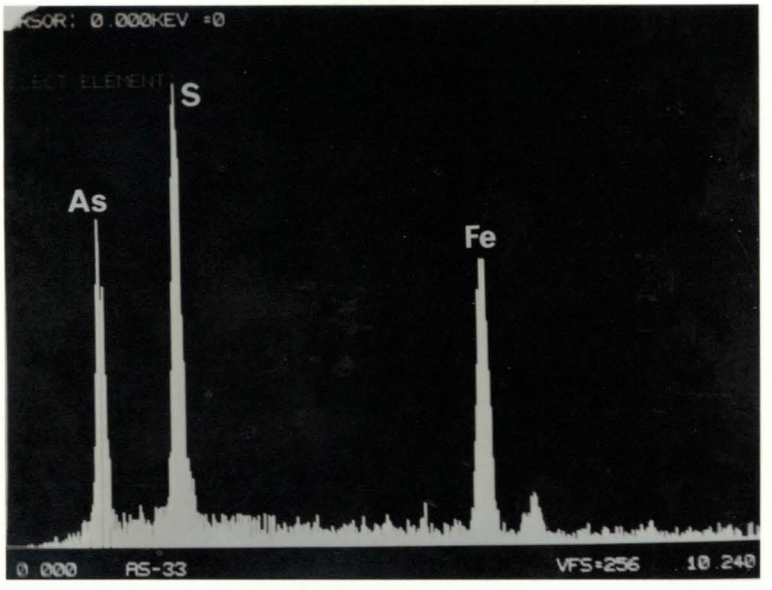
LEAD CONCENTRATE

Sample 2BCD: a composite particle consisting of galena and arsenopyrite (marked by arrow).

The x-ray spectrum is of the arsenopyrite

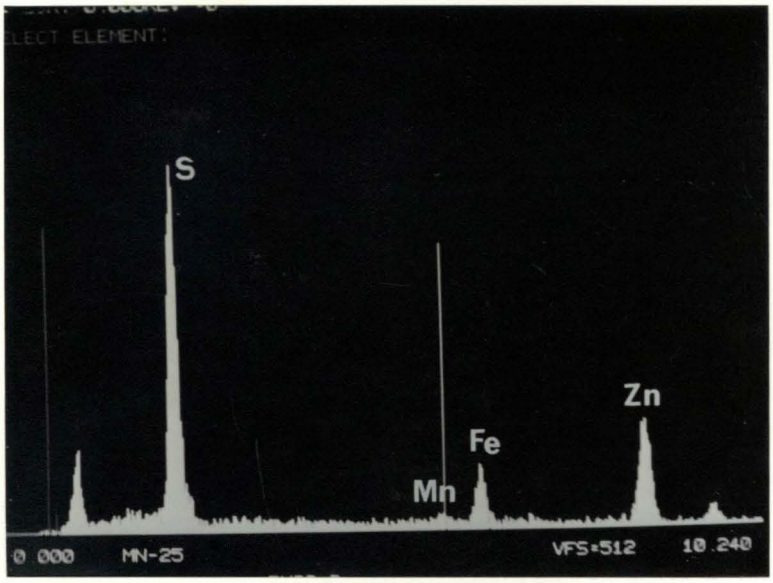
Magnification: 1250x

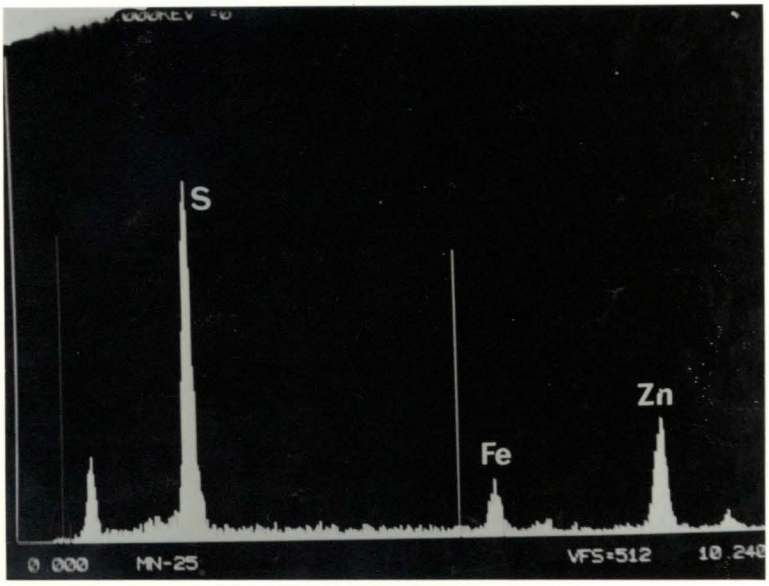

Ga


ASOR: 0.000KEV =0
S
As
Fe
0.000
AS-33
VFS=256
10.240

LEAD CONCENTRATE

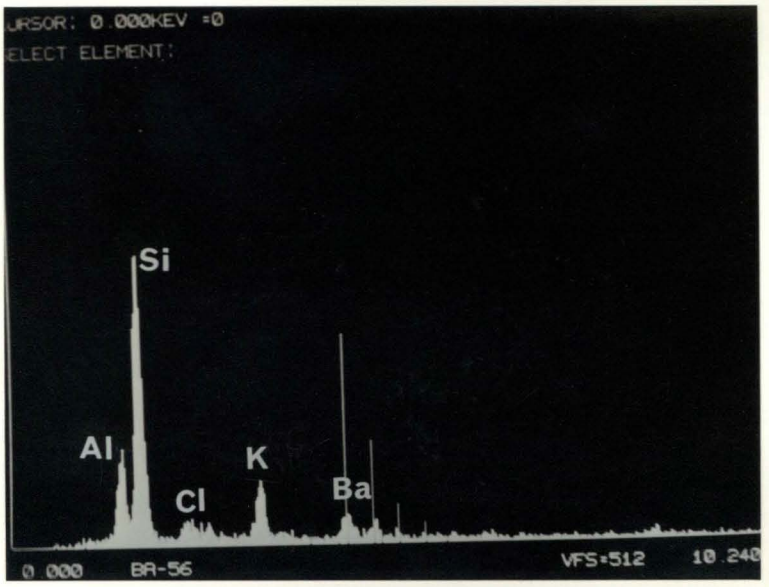
Sample 2BCD: x-ray spectra of two sphalerite grains showing markers at the Mn emission energy position. The top spectrum shows minor amounts of Mn, while the bottom one shows almost no Mn above the limits of detection of the SEM-EDS

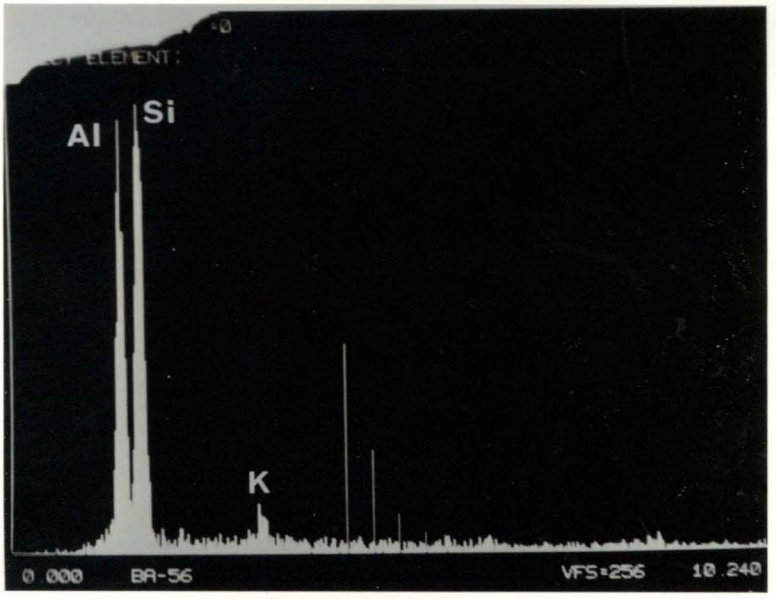

ELECT ELEMENT:
S
Mn
Fe
Zn
0 000
MN-25
VFS=512
10.240

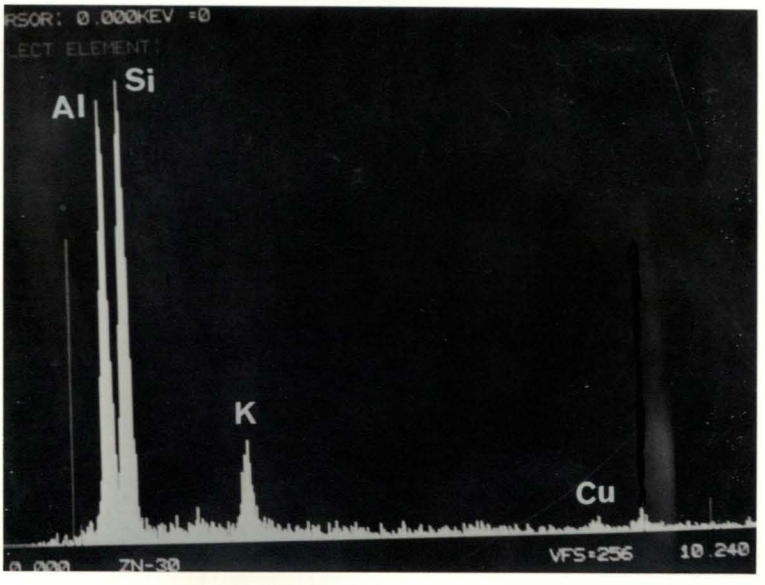

S
Fe
Zn
0 000
MN-25
VFS=512
10.240

LEAD CONCENTRATE

Sample 2BCD: x-ray spectra of muscovite grains showing minor amounts of Ba, no Ba and minor amounts of Cu

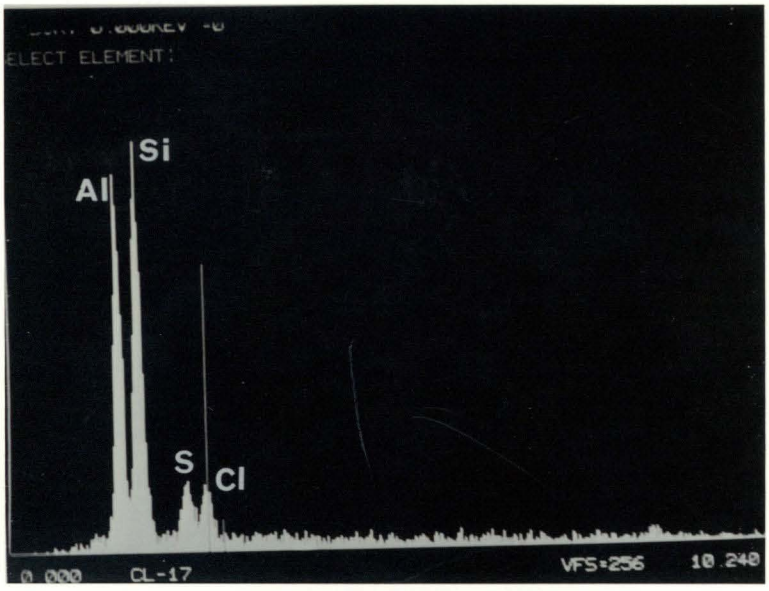

URSOR: 0.000KEV =0
ELECT ELEMENT:
Si
Al
Cl
K
Ba
0.000
BA-56
VFS=512
10.240


ELEMENT:
Si
Al
K
0.000
BA-56
VFS=256
10.240


RSOR: 0.000KEV =0
ECT ELEMENT:
Si
Al
K
Cu
VFS=256
10.240

LEAD CONCENTRATE

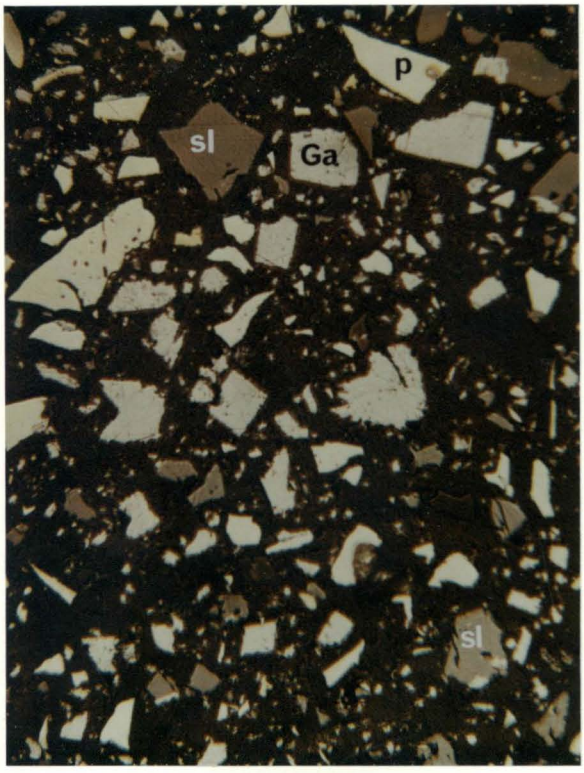
Sample 2BCD: x-ray spectrum of a secondary Si-Al mineral showing minor amounts of S and Cl

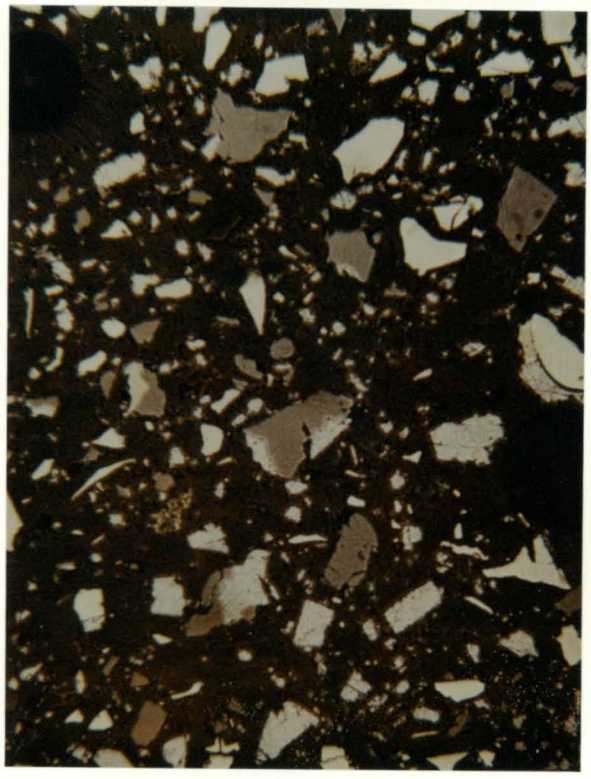

ELECT ELEMENT:
Si
Al
S
Cl
0.000
CL-17
VFS=256
10.240

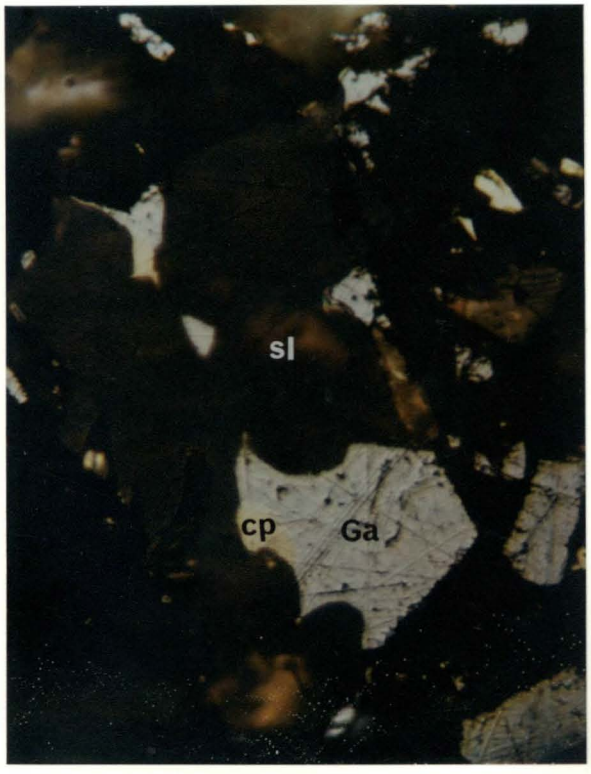
LEAD CONCENTRATE

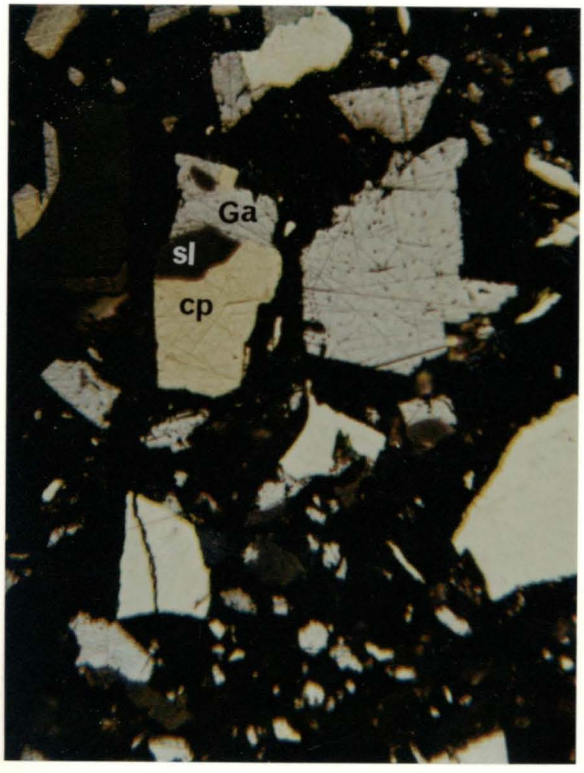
Sample 2EF: particles of galena, sphalerite, pyrite and chalcopyrite photographed by using magnifications of 200x (top two photomicrographs), 1250x (bottom left photomicrograph) and 500x (bottom right photomicrograph).

Galena and sphalerite occur both as liberated grains and associated


p
sl
Ga
sl



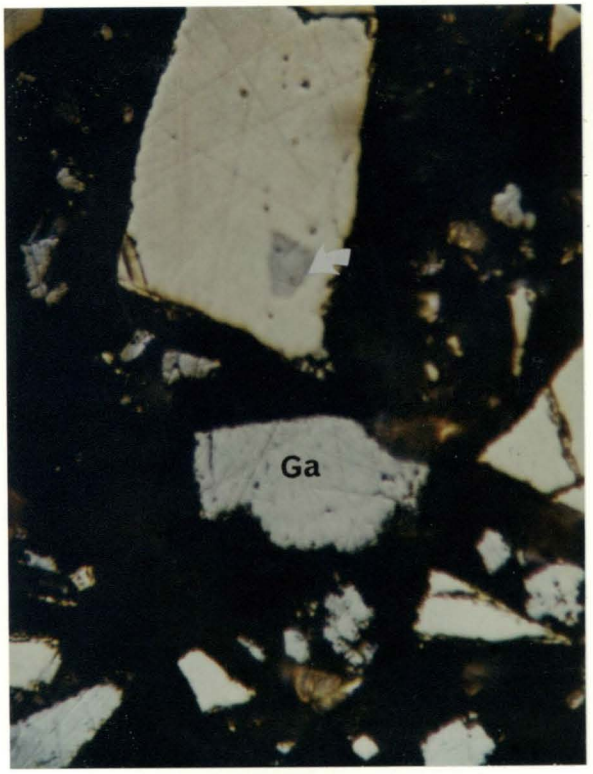

sl
cp
Ga


Ga
sl
cp

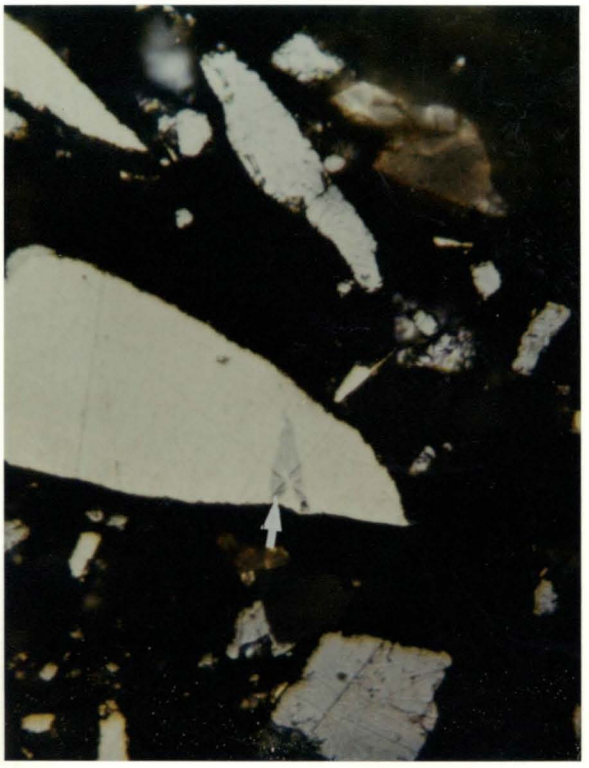
LEAD CONCENTRATE

Sample 2EF: particles of galena liberated and associated with pyrite

Magnification: 1250x


Ga


Ga



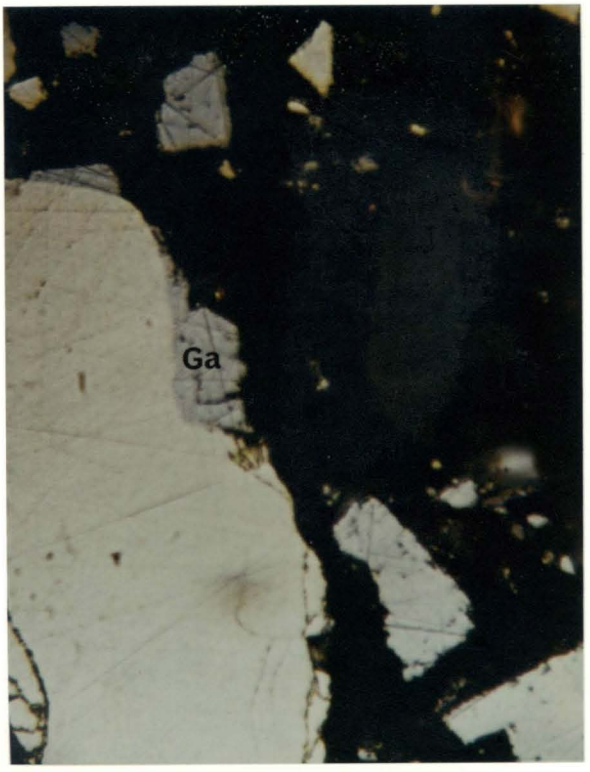
LEAD CONCENTRATE

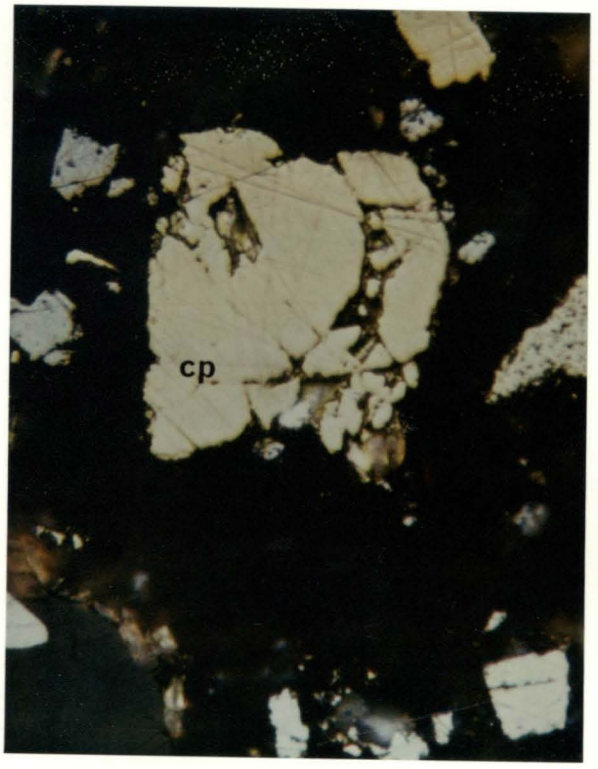
Top left photomicrograph: sample 2EF, particles of galena liberated and associated with pyrite;

Top right photomicrograph: sample 2EF, a liberated particle of chalcopyrite;

Bottom photomicrograph: sample 2EF, blue grain of Ti-Cl composition

Magnifications: 1250x for the top photomicrographs, 500x for the bottom photomicrograph


Ga


cp

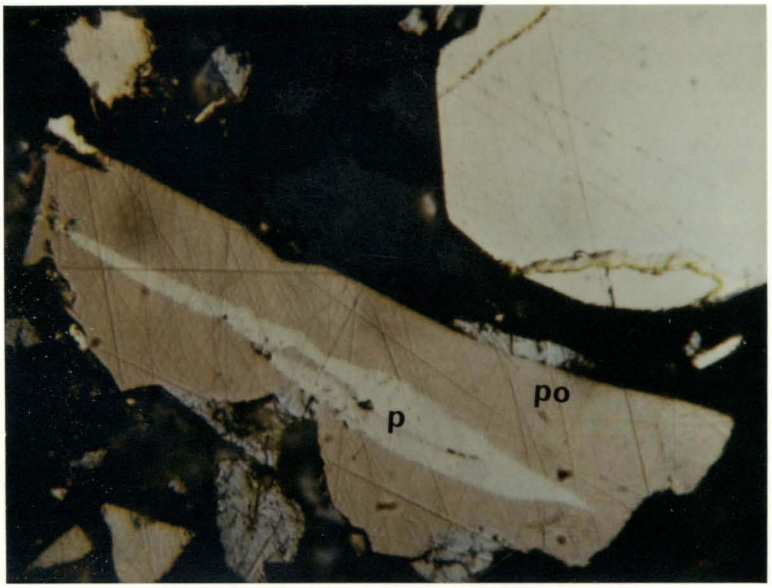

Ti Cl

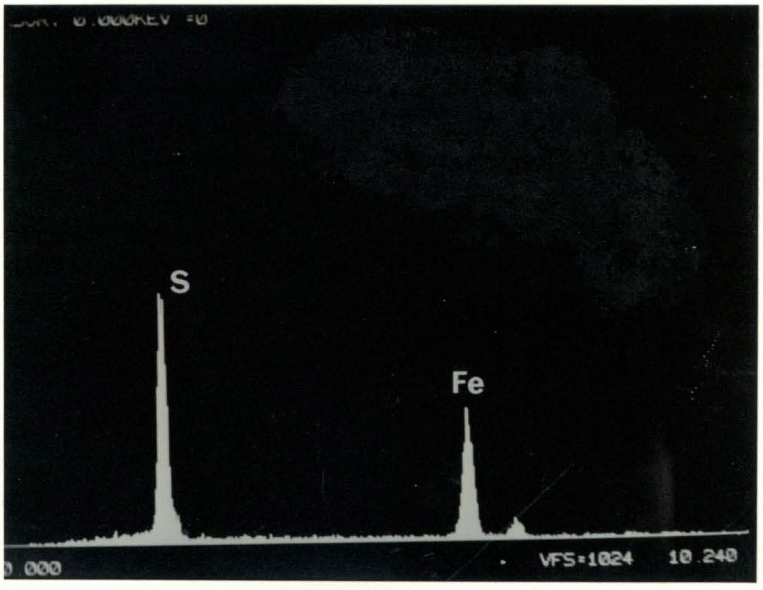
LEAD CONCENTRATE

Sample 2EF: composite particle of pyrite-pyrrhotite-galena.

The x-ray spectrum is of the pyrrhotite

Magnification: 1250x


p
po

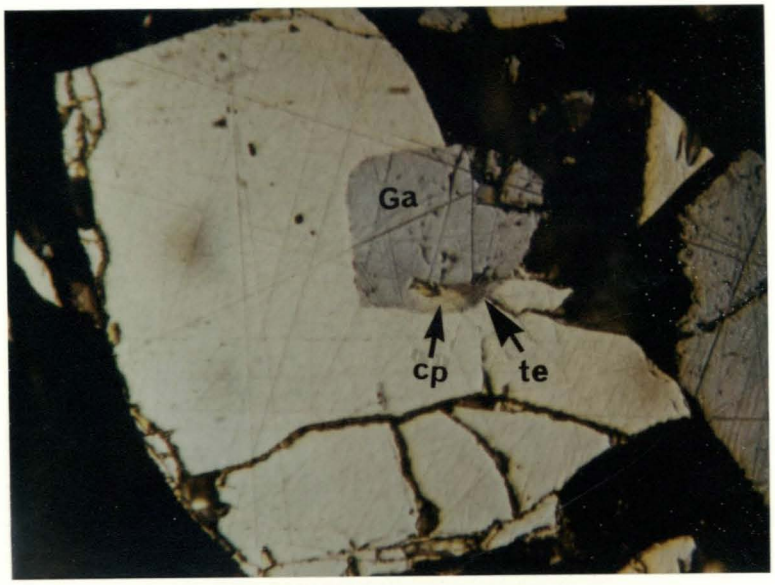

S
Fe
VFS=1024
10.240

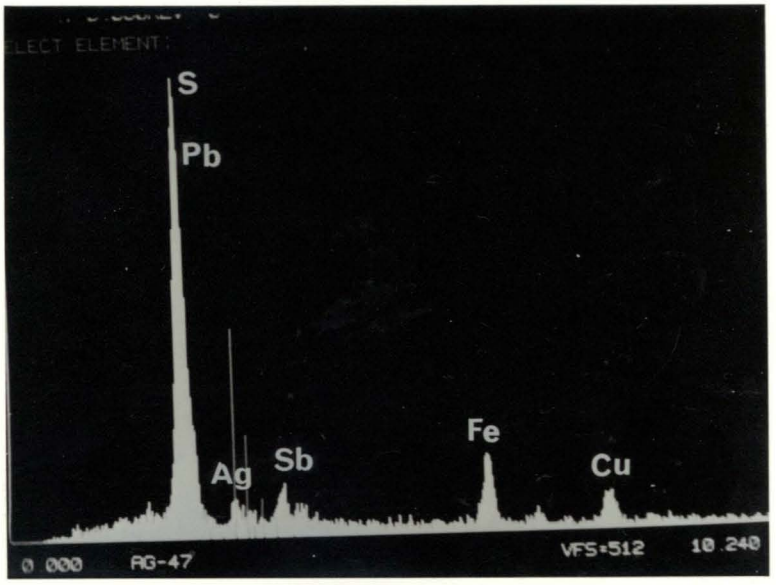
LEAD CONCENTRATE

Sample 2EF: very fine particle of tetrahedrite (marked te) associated with galena and chalcopyrite and enclosed in pyrite.

The x-ray spectrum is of the tetrahedrite

Magnification: 1250x


Ga
cp
te

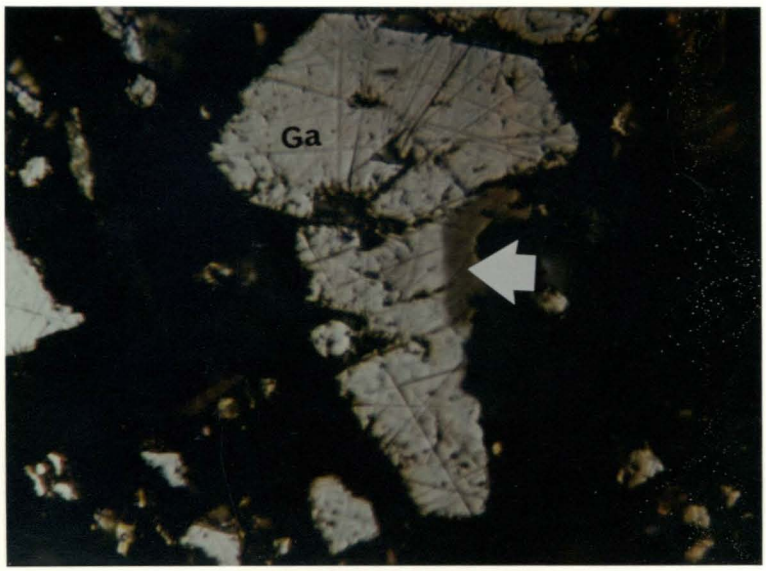

S
Pb
Ag
Sb
Fe
Cu
0 000
AG-47
VFS=512
10.240

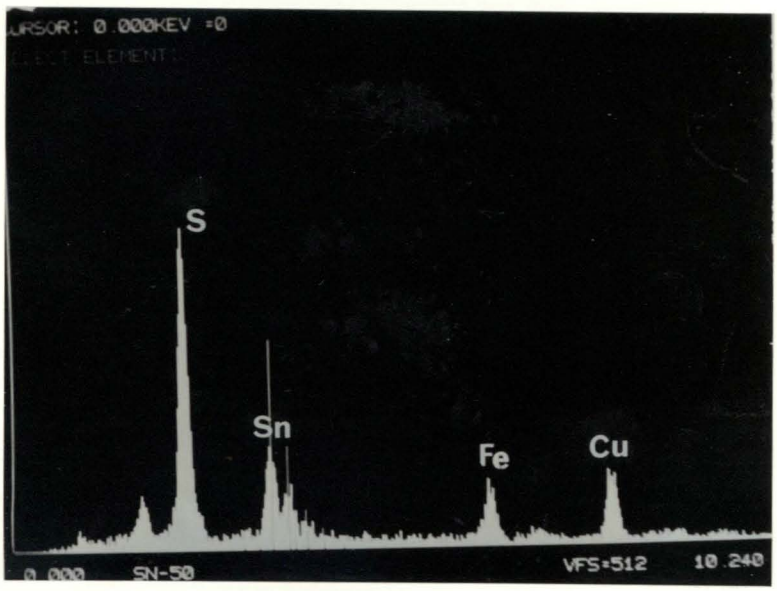
LEAD CONCENTRATE

Sample 2EF: a small grain of stannite attached to a larger particle of galena.

The x-ray spectrum is of the stannite

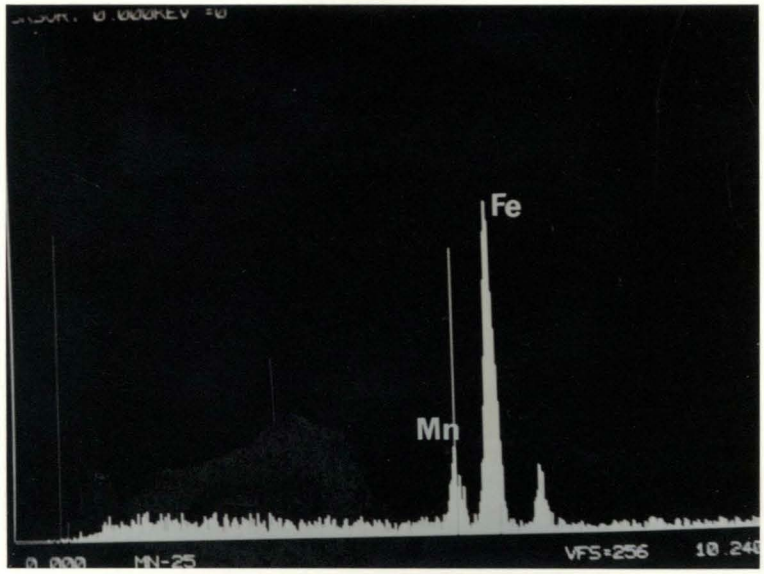
Magnification:1250x

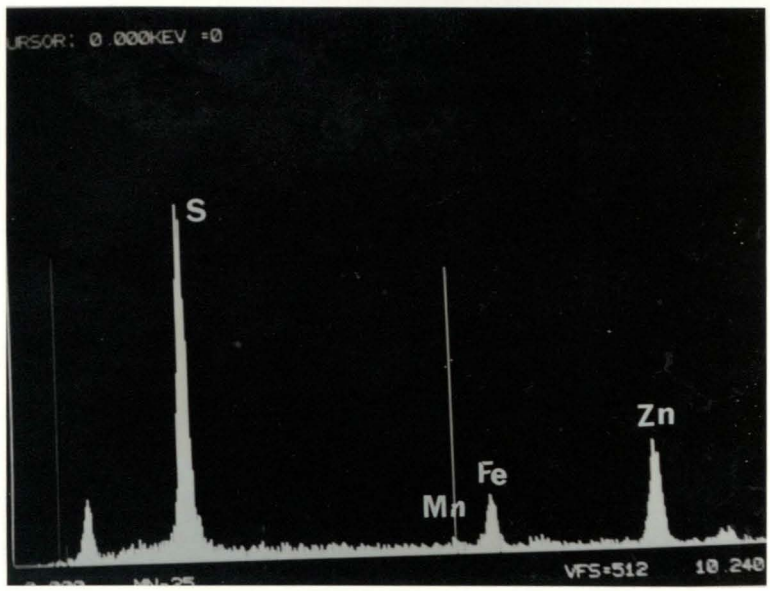

Ga

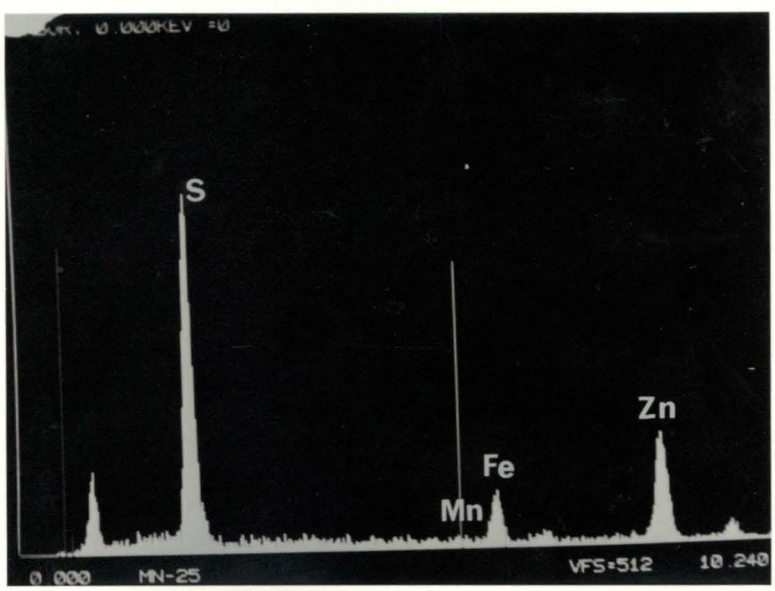

URSOR: 0.000KEV =0
S
Sn
Fe
Cu
0.000
SN-50
VFS=512
10.240

LEAD CONCENTRATE

Sample 2EF: x-ray spectra of Fe carbonate (top) and of sphalerite showing minor amounts of Mn

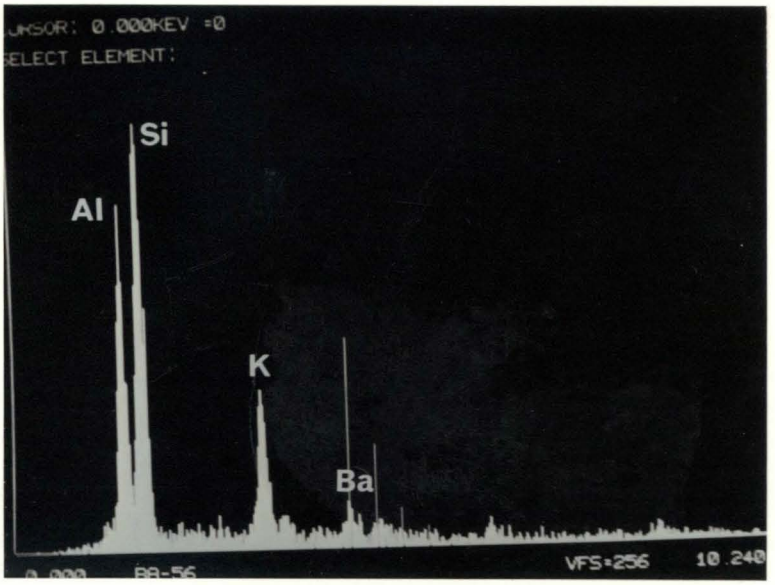

Fe
Mn
VFS=256
10.240


URSOR: 0.000KEV =0
S
Zn
Fe
Mn
VFS=512
10.240


S
Zn
Fe
Mn
0.000
MN-25
VFS=512
10.240

LEAD CONCENTRATE

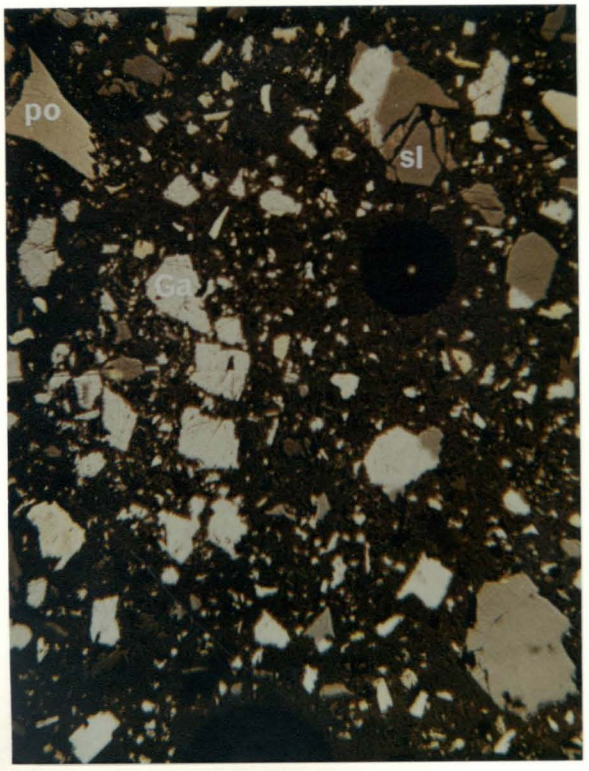
Sample 2EF: x-ray spectrum of muscovite showing minor amounts of Ba

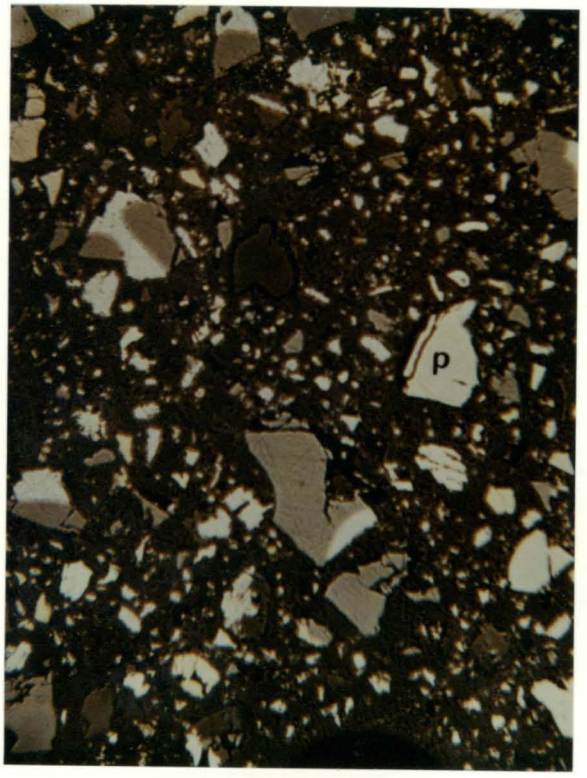

UKSOR: 0.000KEV =0
ELECT ELEMENT:
Si
Al
K
Ba
VFS=256
10.240

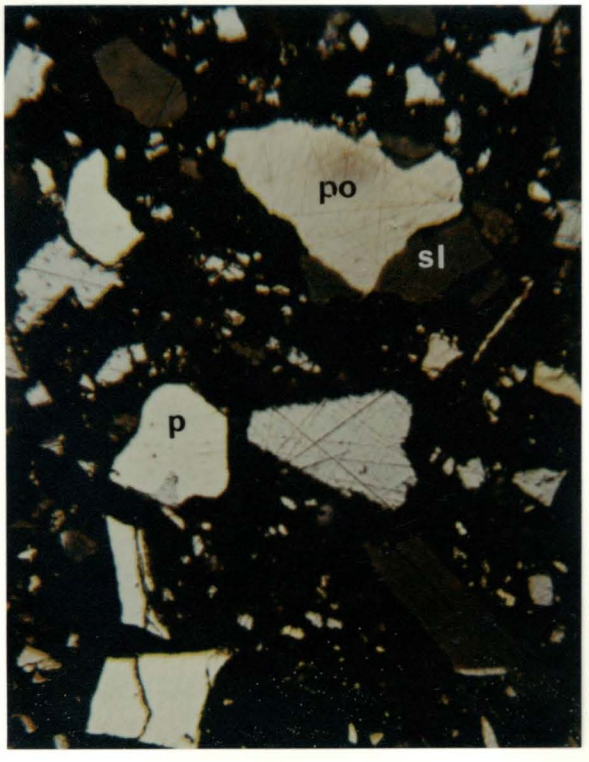
LEAD CONCENTRATE

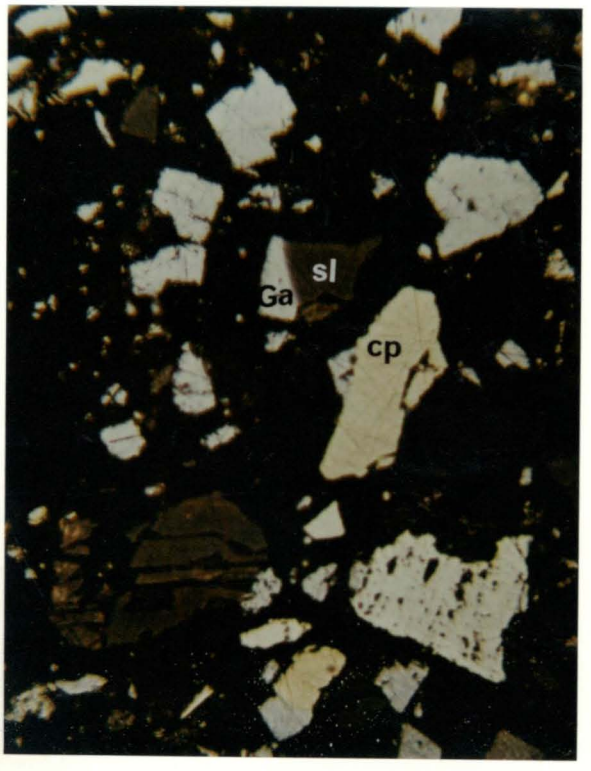
Sample 2H: particles of galena, sphalerite, pyrite, pyrrhotite and chalcopyrite photographed by using magnifications of 200x (top two photomicrographs) and 500x (bottom two photomicrographs).

Galena and sphalerite occur both as liberated grains and associated


po
sl
Ga


p

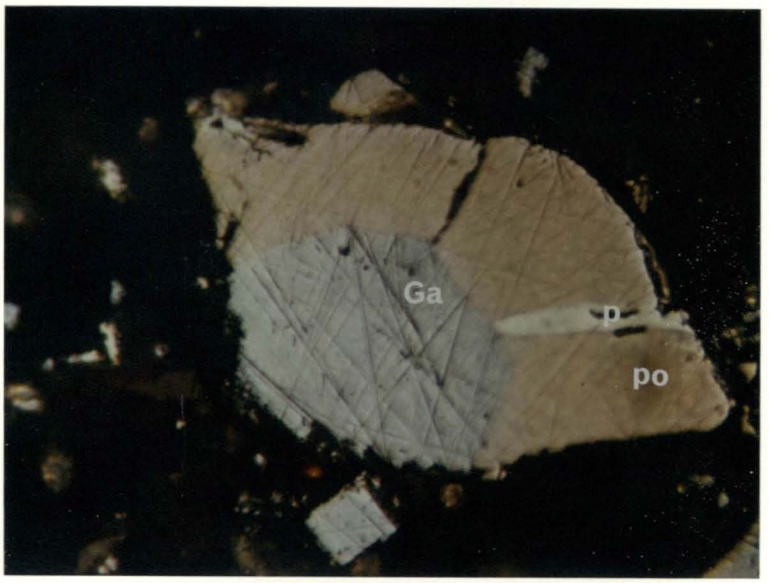

po
sl
p

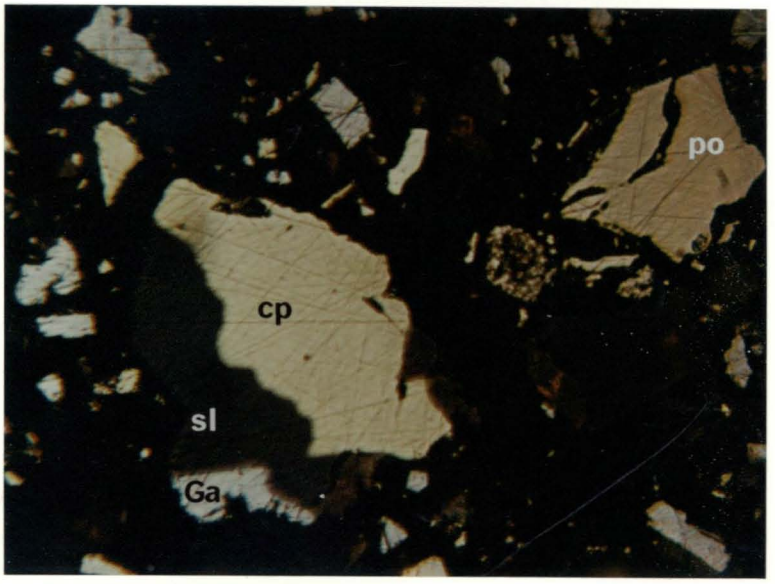

sl
Ga
cp

LEAD CONCENTRATE

Sample 2H: composite grains of galena-pyrite-pyrrhotite and galena-sphalerite-chalcopyrite

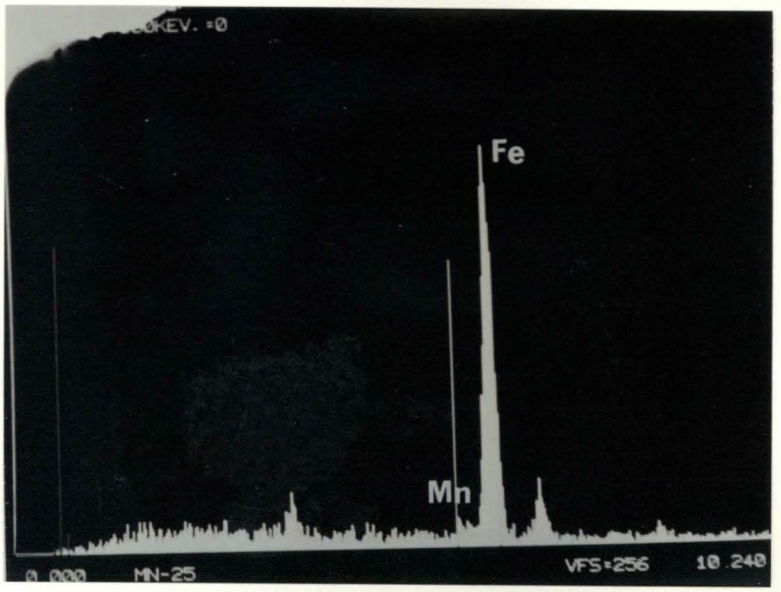
Magnifications: 1250x for the top photomicrograph and 500x for the bottom photomicrograph

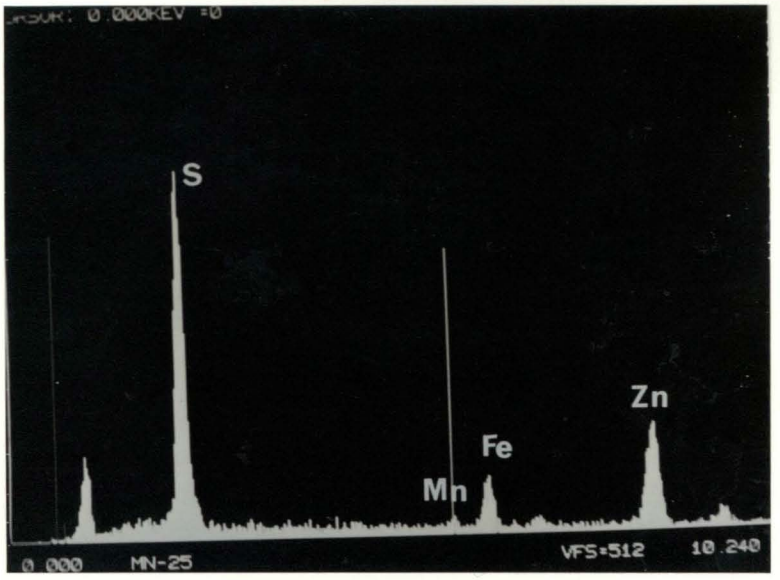

Ga
po

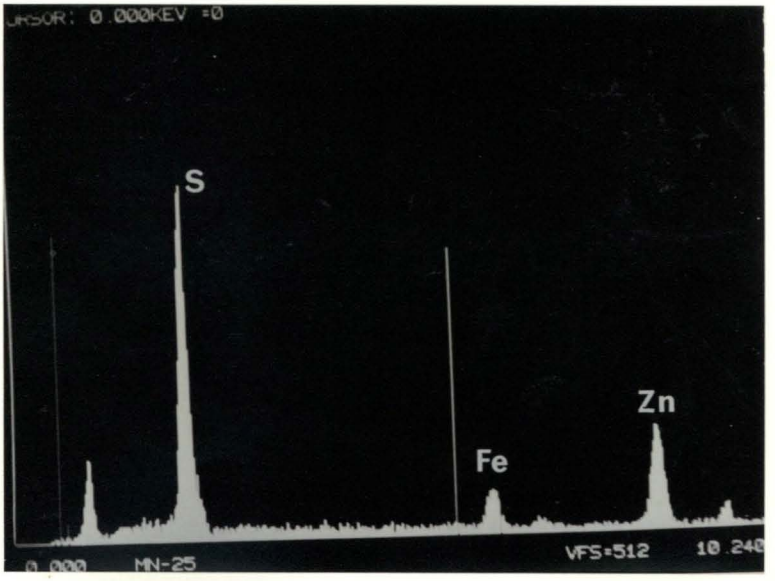

po
cp
sl
Ga

LEAD CONCENTRATE

Sample 2H: x-ray spectra of Fe carbonate (top) and of sphalerite showing minor to very minor amounts of Mn


Fe
Mn
0.000
MN-25
VFS=256
10.240

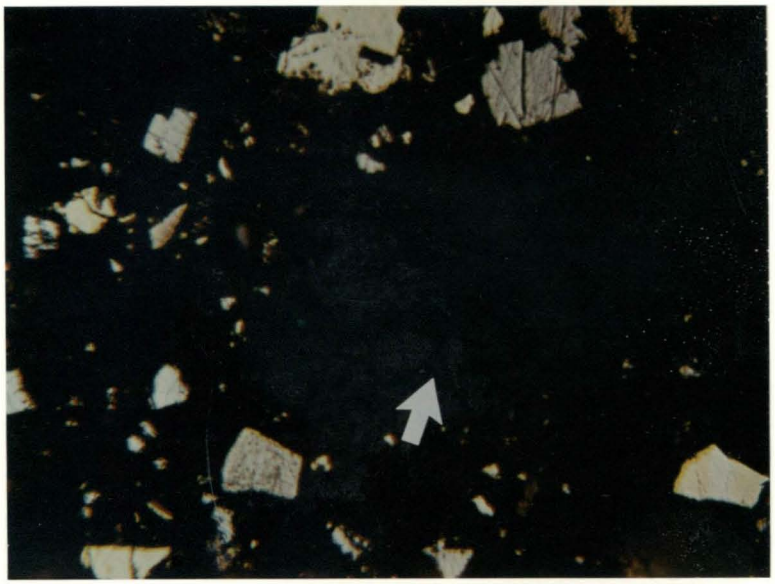

0.000KEV =0
S
Zn
Fe
Mn
0.000
MN-25
VFS=512
10.240

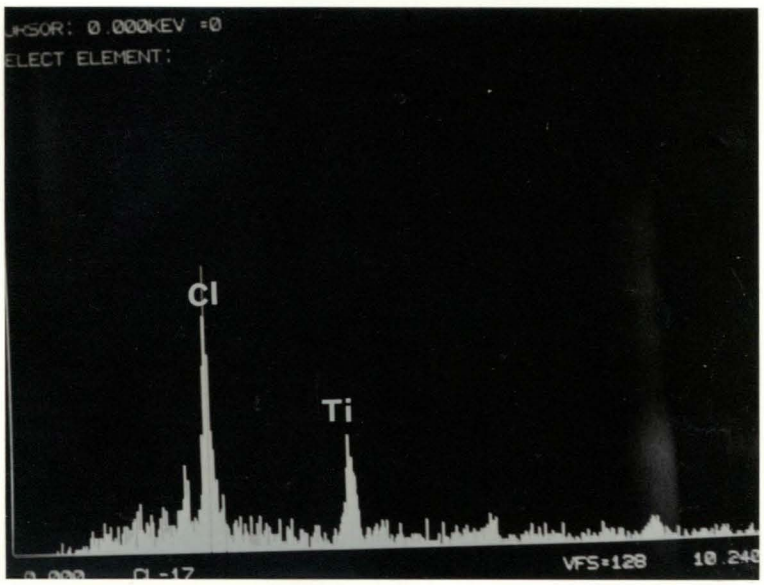

0.000KEV =0
S
Zn
Fe
0.000
MN-25
VFS=512

LEAD CONCENTRATE

Sample 2H: blue grain of Ti-Cl composition

Magnification: 500x

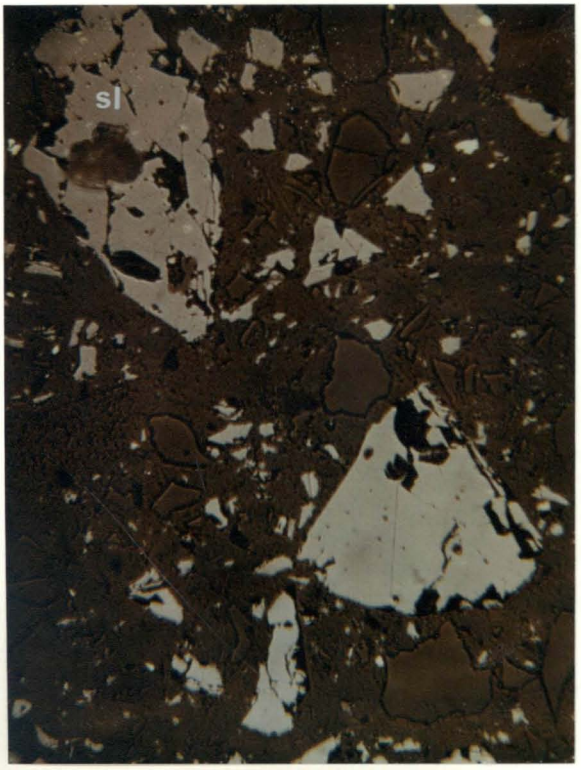


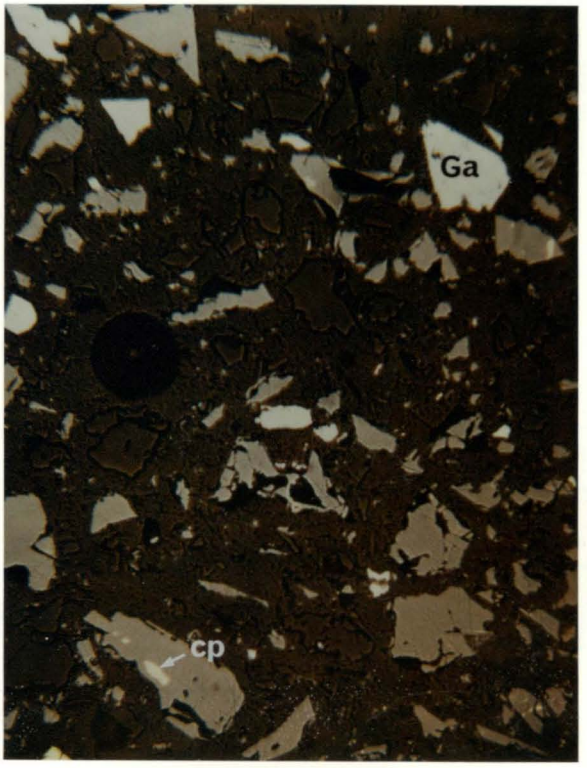

ELECT ELEMENT:
Cl
Ti
VFS=128

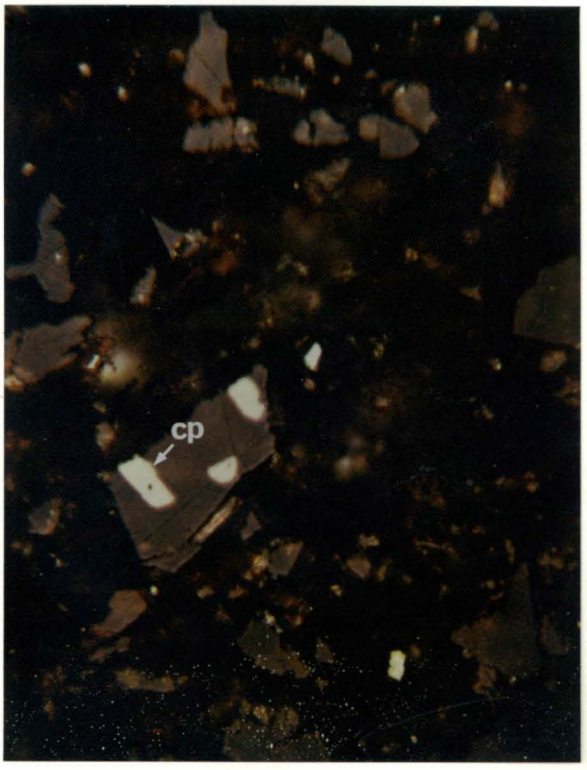
ZINC CONCENTRATE

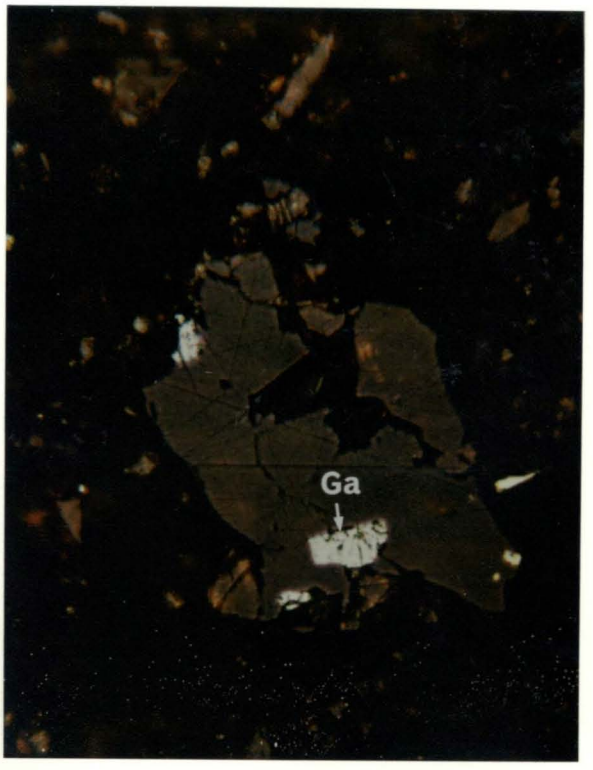
Sample 2A: particles of sphalerite, galena and chalcopyrite photographed by using magnifications of 200x (top two photomicrographs) and 500x (bottom two photomicrographs).

Most of the sphalerite particles are liberated. The galena is liberated and associated with the sphalerite. The chalcopyrite is associated with the sphalerite


sl


Ga
cp

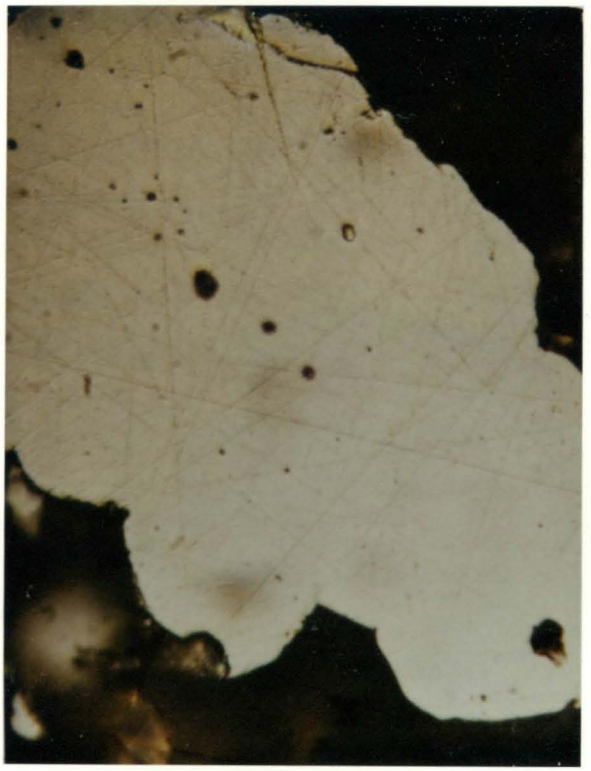

cp


Ga

ZINC CONCENTRATE

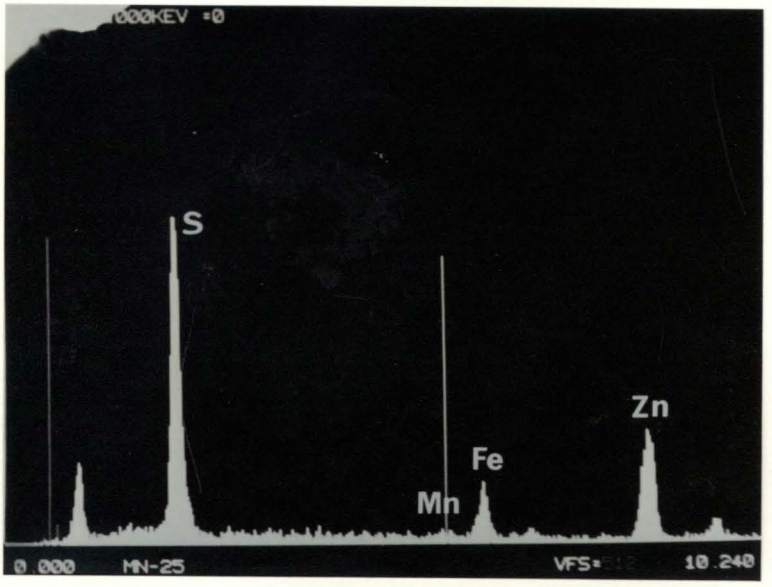
Sample 2A: very fine inclusions of galena in pyrite

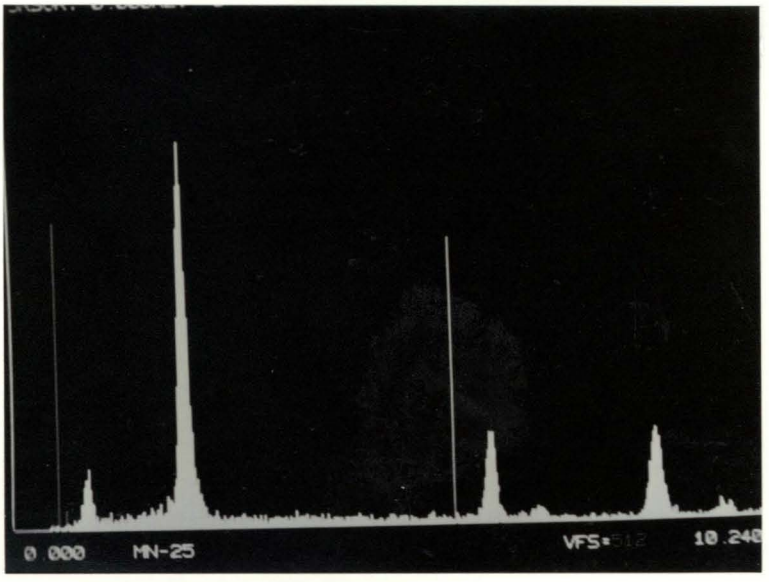
Magnification: 1250x



ZINC CONCENTRATE

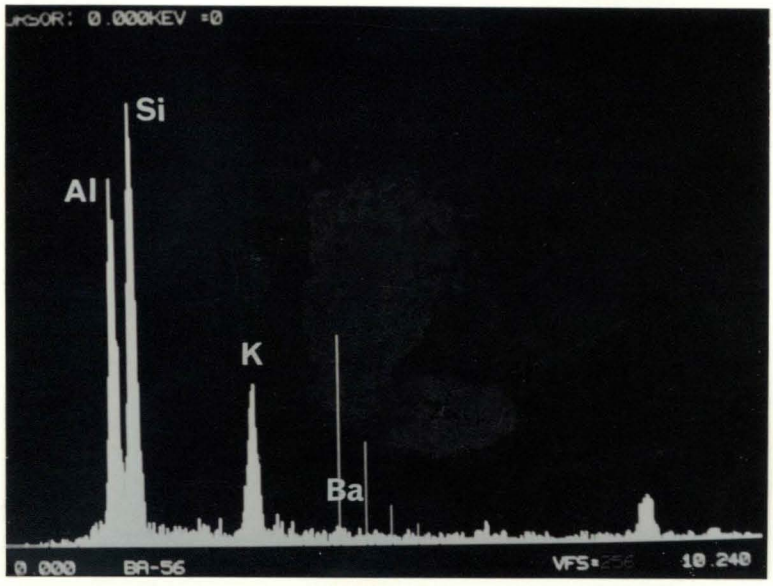
Sample 2A: x-ray spectra of sphalerite showing minor Mn (top) and no Mn above the limits of detection of the SEM-EDS

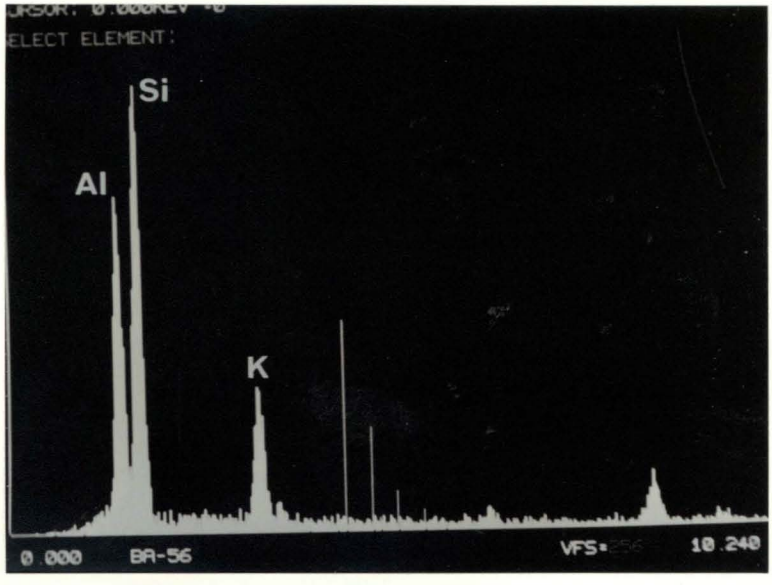

000KEV =0
S
Mn
Fe
Zn
0.000
MN-25
10.240


0.000
MN-25

ZINC CONCENTRATE

Sample 2A: x-ray spectra of muscovite, showing minor Ba (top) and no Ba above the limits of detection of the SEM-EDS

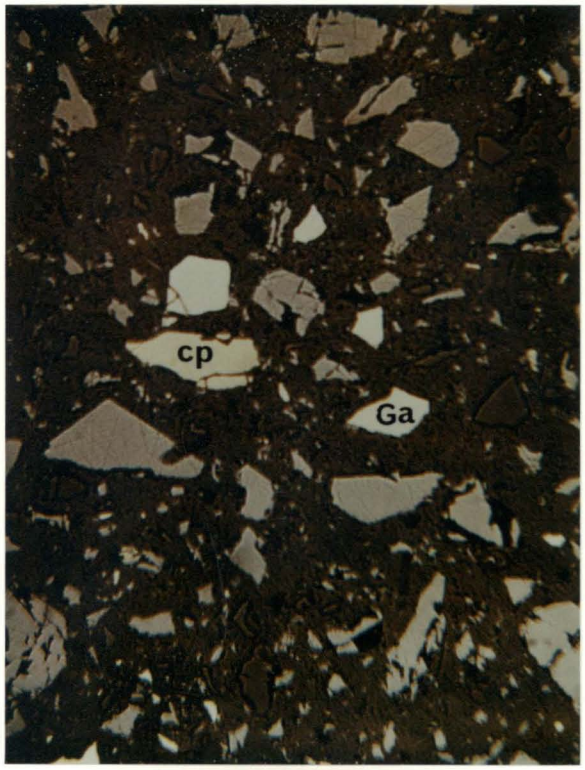

Si
Al
K
Ba
0.000
BA-56
10.240

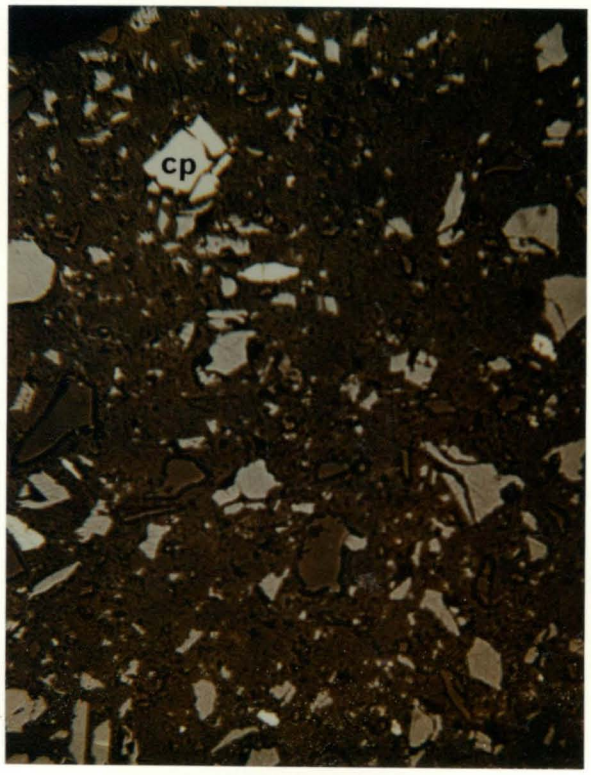

ELECT ELEMENT:
Si
Al
K
0.000
BA-56
10.240

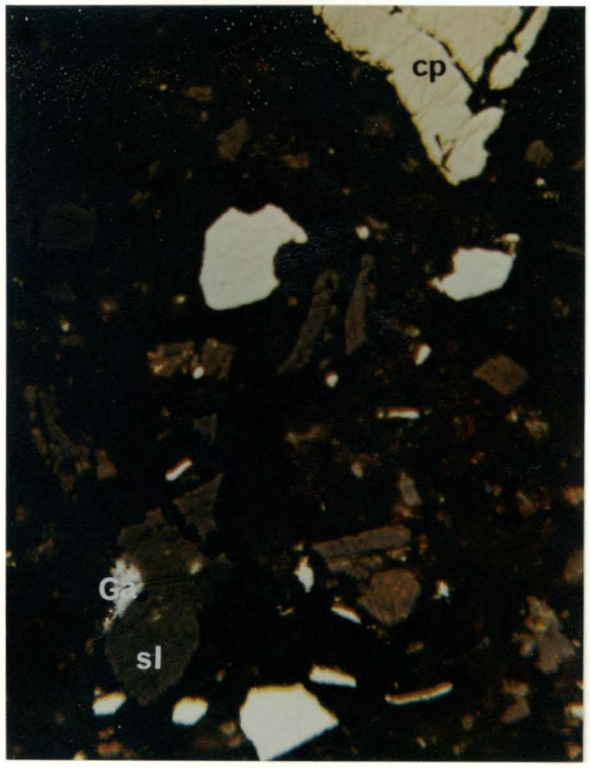
ZINC CONCENTRATE

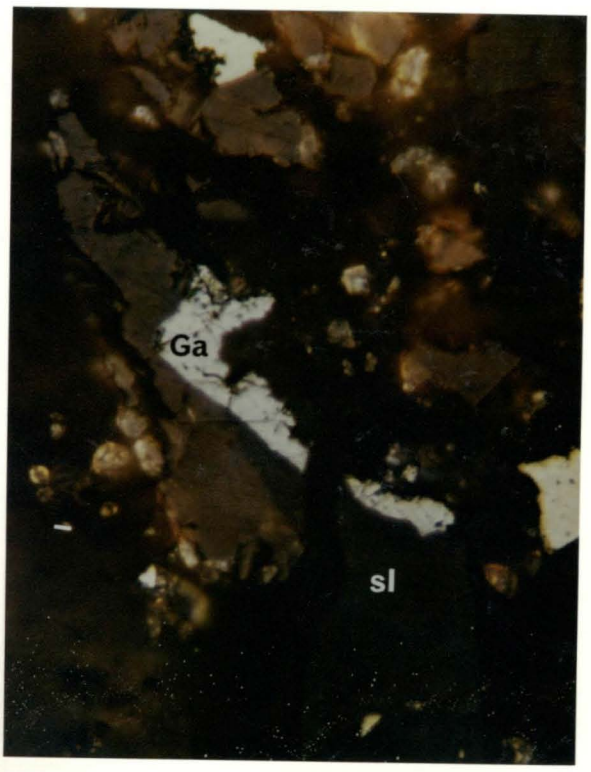
Sample 2BCD: particles of sphalerite, galena and chalcopyrite photographed by using magnifications of 200x (top two photomicrographs), 500x (bottom left photomicrograph) and 1250x (bottom right photomicrograph).

Most of the sphalerite particles are liberated. The chalcopyrite particles are liberated. The galena particles are liberated and attached to sphalerite


cp
Ga


cp

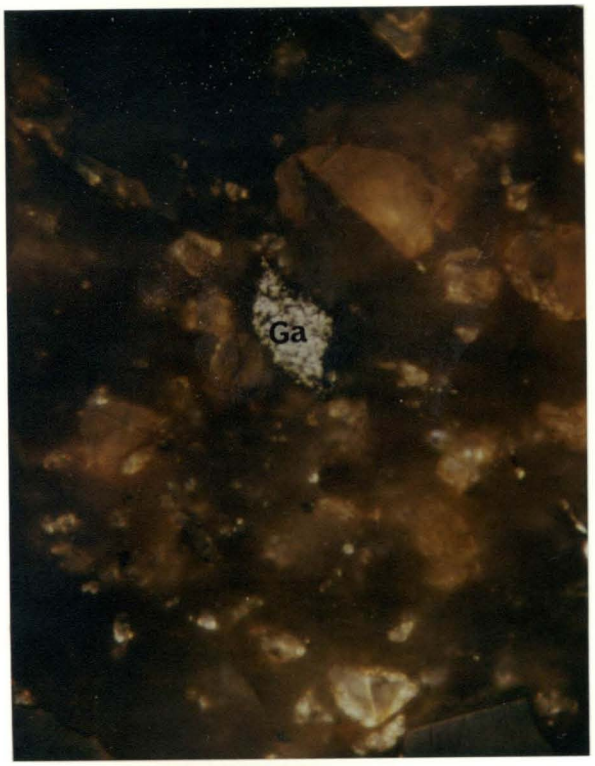

cp
sl


Ga
sl

ZINC CONCENTRATE

Sample 2BCD: particles of galena liberated and associated with sphalerite

Magnification: 1250x


Ga

ZINC CONCENTRATE

Sample 2BCD: fine particles of galena associated with pyrite

Magnification: 1250x

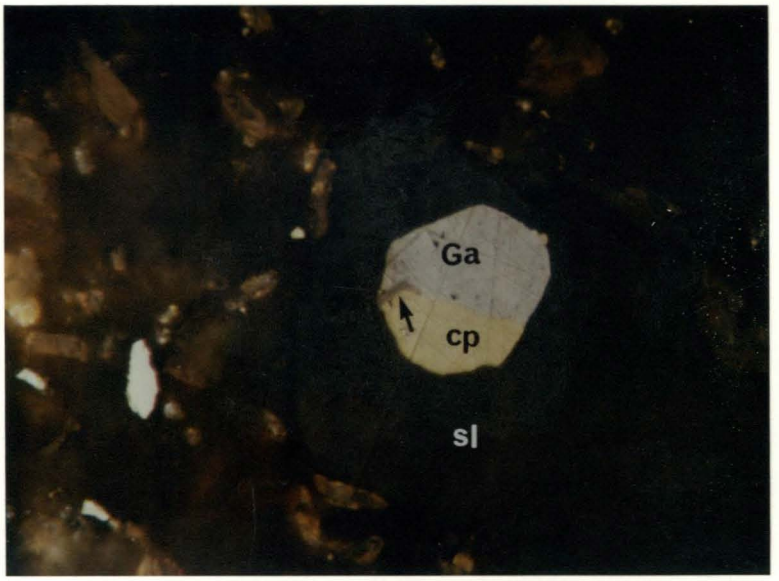

Ga

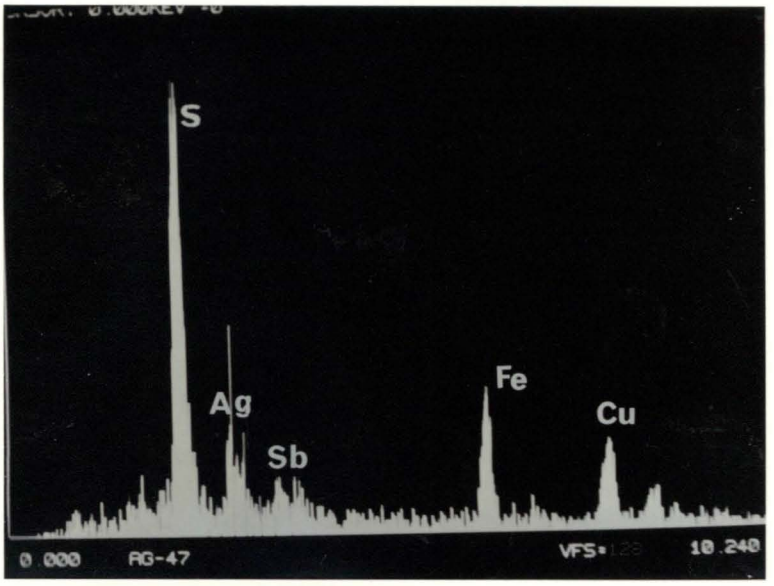
ZINC CONCENTRATE

Sample 2BCD: very fine particle of tetrahedrite associated with galena and chalcopyrite and enclosed in sphalerite.

The x-ray spectrum is of the tetrahedrite

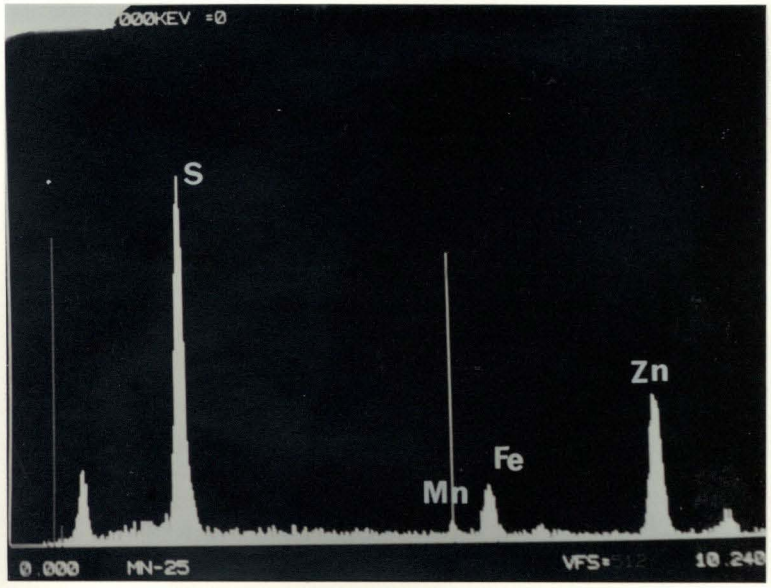
Magnification: 1250x

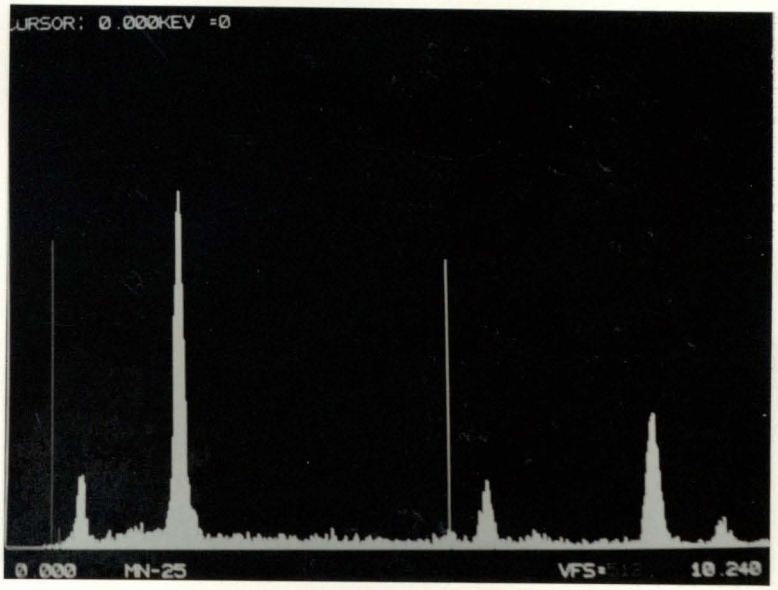

Ga
cp
sl

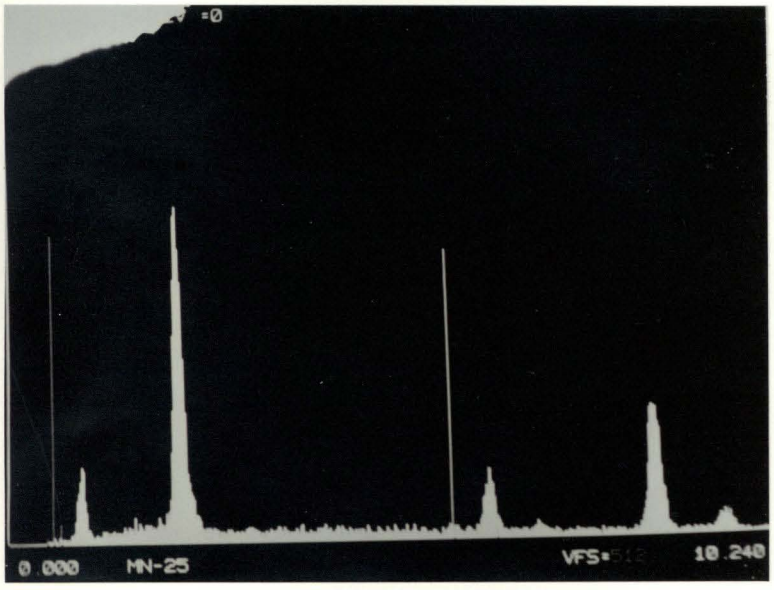

S
Ag
Sb
Fe
Cu
0.000
AG-47
10.240

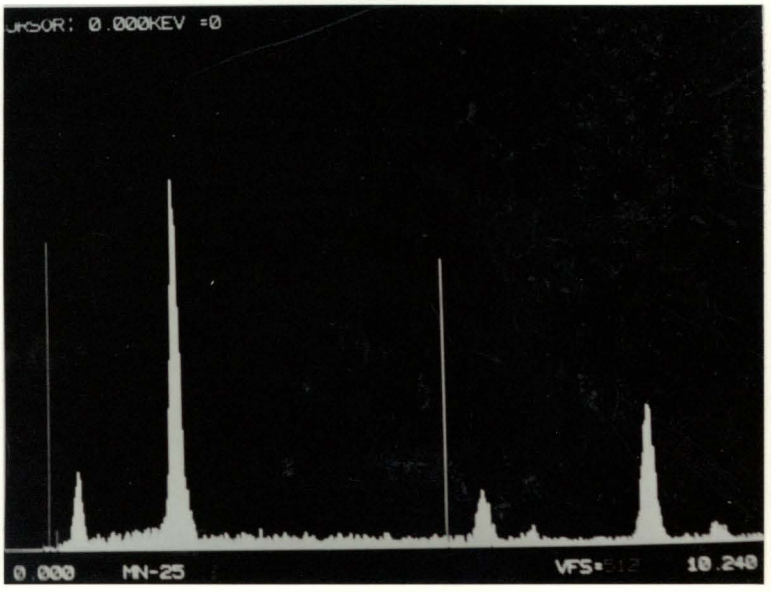
ZINC CONCENTRATE

Sample 2BCD: x-ray spectra of sphalerite showing minor and no Mn above the limits of detection of the SEM-EDS


S
Mn
Fe
Zn
0.000
MN-25
10.240

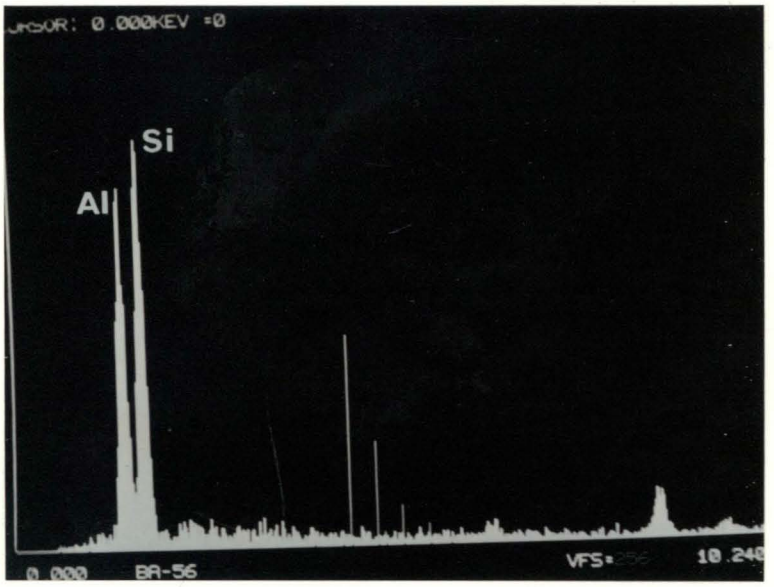

0.000
MN-25
10.240


0.000
MN-25
10.240


0.000
MN-25
10.240

ZINC CONCENTRATE

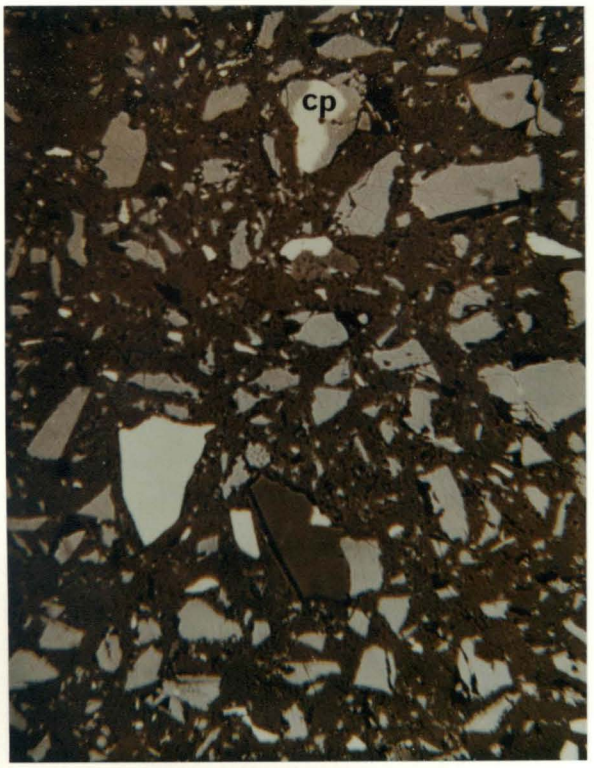
Sample 2BCD: x-ray spectrum of a Si-Al probably secondary mineral

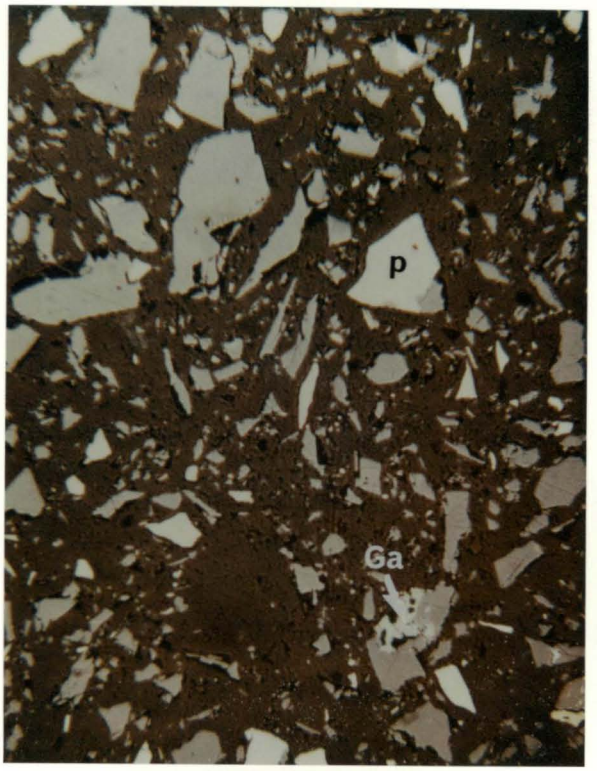

Si
Al
BA-56

ZINC CONCENTRATE

Sample 2EF: particles of sphalerite, pyrite, chalcopyrite and galena photographed by using magnifications of 200x (top two photomicrographs), 500x (bottom left photomicrograph) and 1250x (bottom right photomicrograph).

Most of the sphalerite particles are liberated. The chalcopyrite and galena are associated with sphalerite


cp


p
Ga


cp

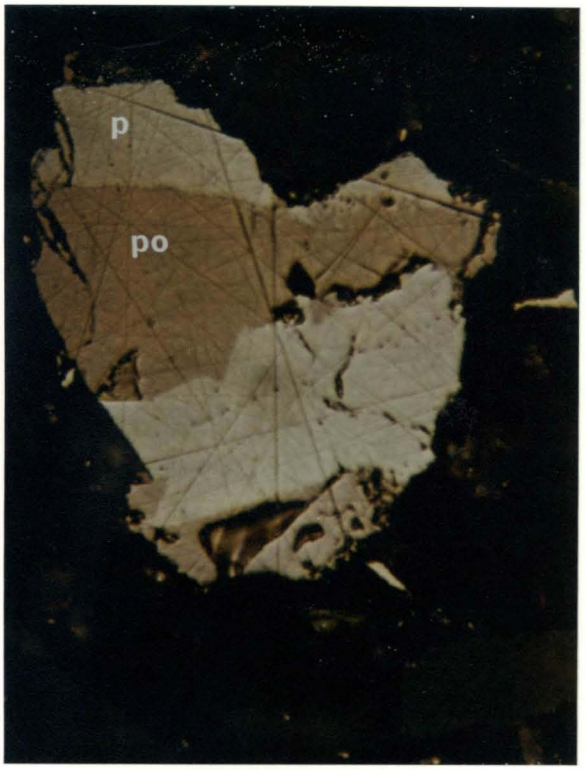

sl
Ga

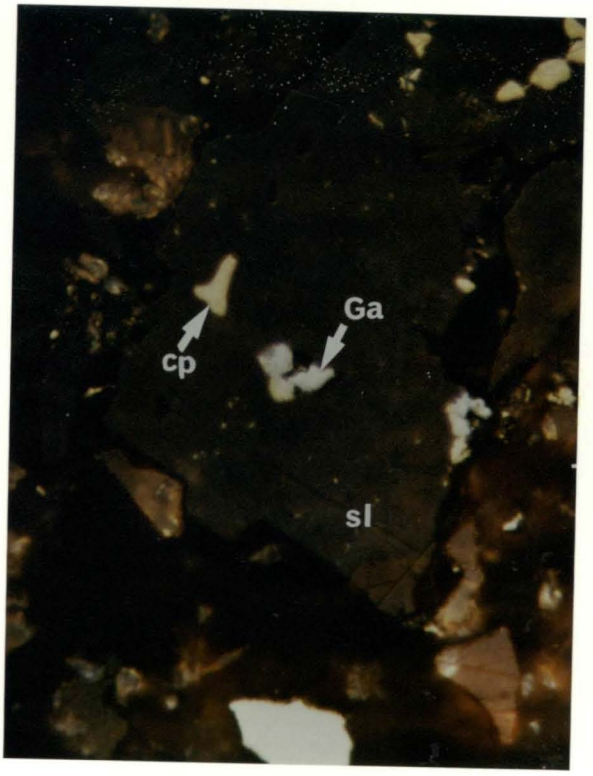
ZINC CONCENTRATE

Left: sample 2EF, composite pyrite-pyrrhotite particle;

Right: sample 2EF, fine particles of galena and chalcopyrite enclosed in sphalerite

Magnification: 1250x


p
po

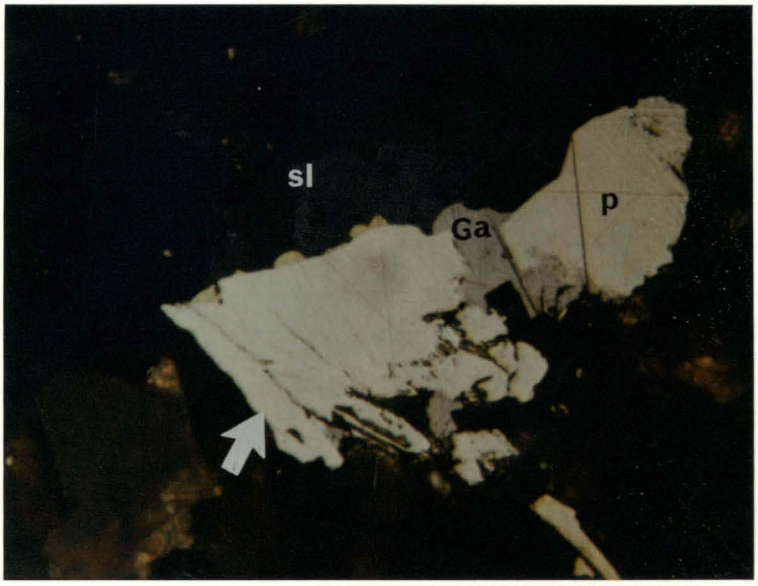

cp
Ga
sl

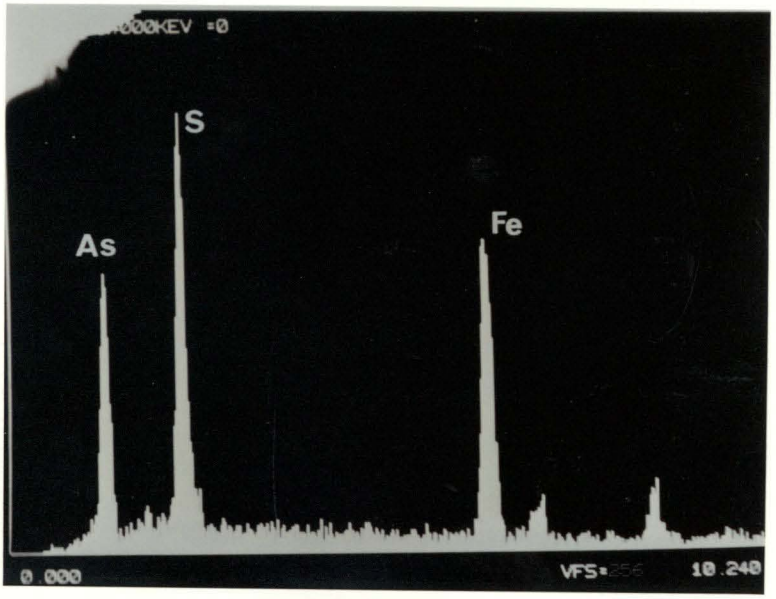
ZINC CONCENTRATE

Sample 2EF: a composite particle consisting of sphalerite, galena, pyrite and arsenopyrite (marked by arrow).

The x-ray spectrum is of the arsenopyrite

Magnification: 1250x


sl
Ga
p

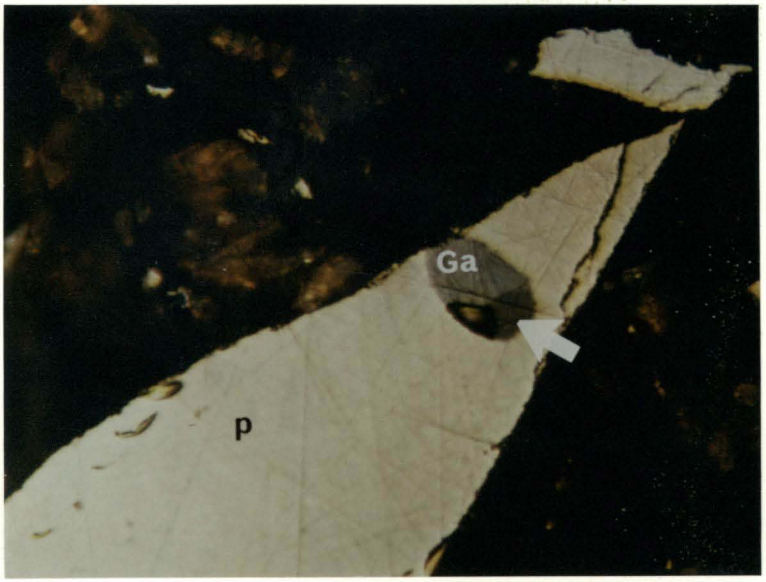

.000KEV =0
S
As
Fe
0.000
VFS=256
10.240

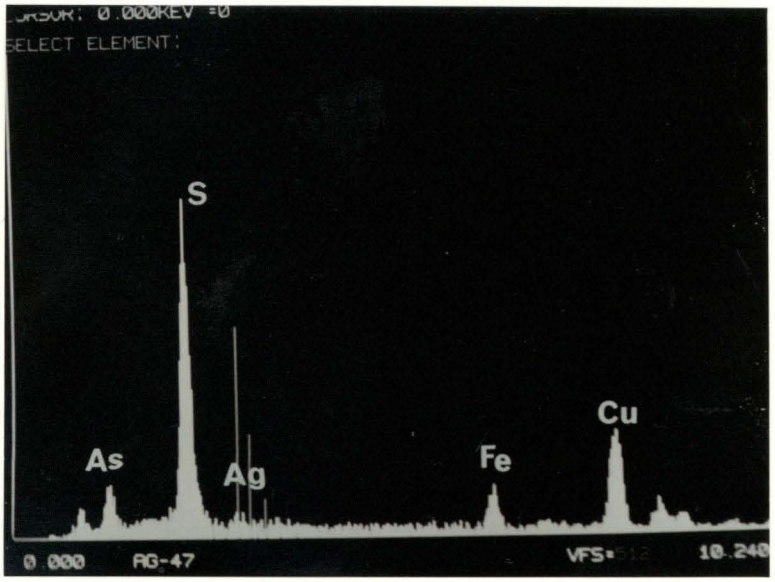
ZINC CONCENTRATE

Sample 2EF: a particle of tetrahedrite-tennantite associated with galena and enclosed in pyrite.

The x-ray spectrum is of the tetrahedrite-tennantite.

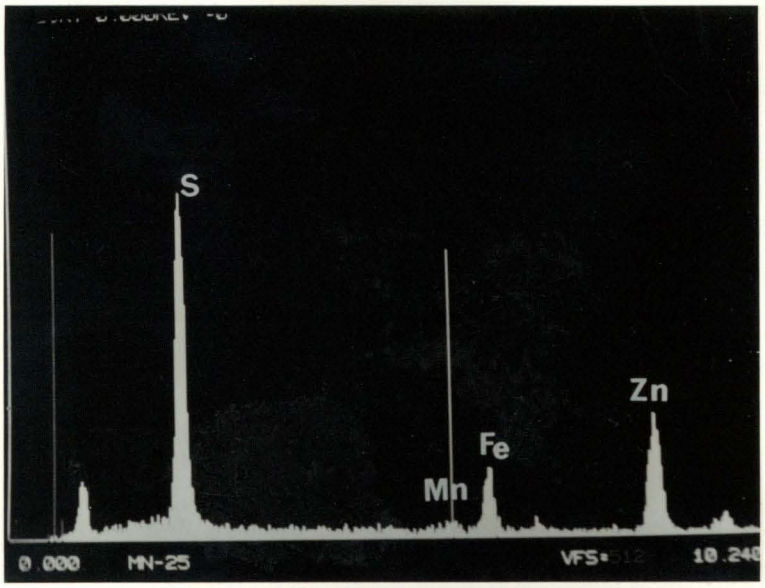
Magnification: 1250x

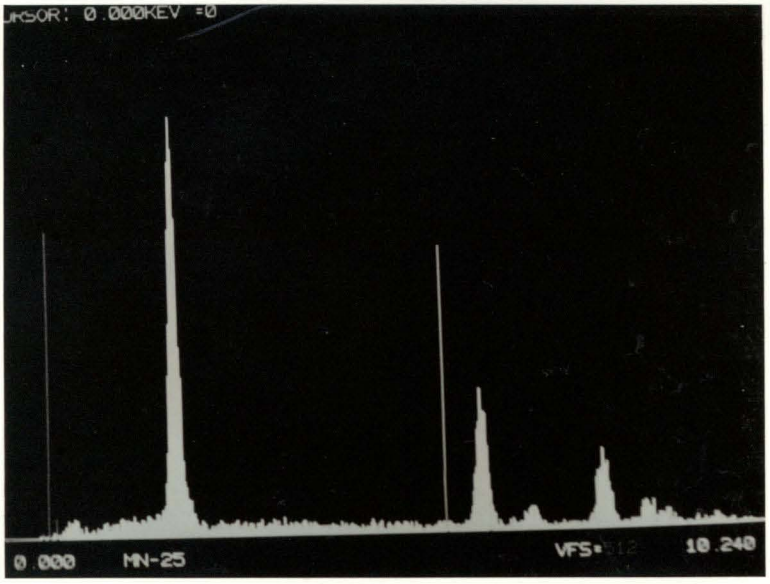

Ga
p

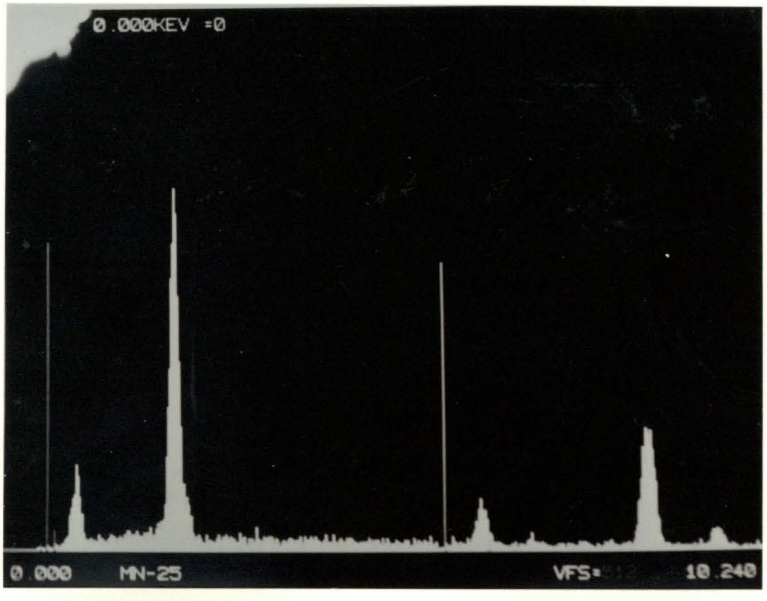

CURSOR: 0.000KEV =0
SELECT ELEMENT:
S
As
Ag
Fe
Cu
0.000
AG-47
10.240

ZINC CONCENTRATE

Sample 2EF: x-ray spectra of sphalerite showing minor and no Mn above the limits of detection of the SEM-EDS


S
Mn
Fe
Zn
0.000
MN-25

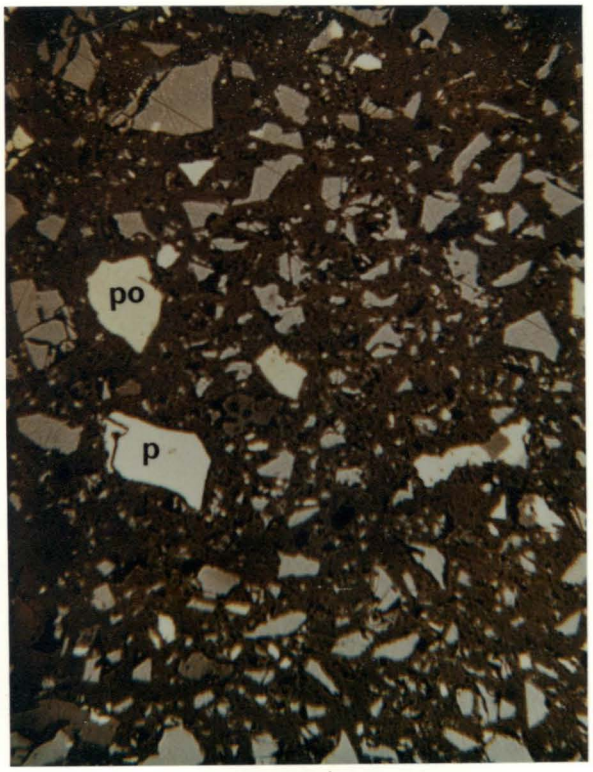

0.000KEV =0
0.000
MN-25

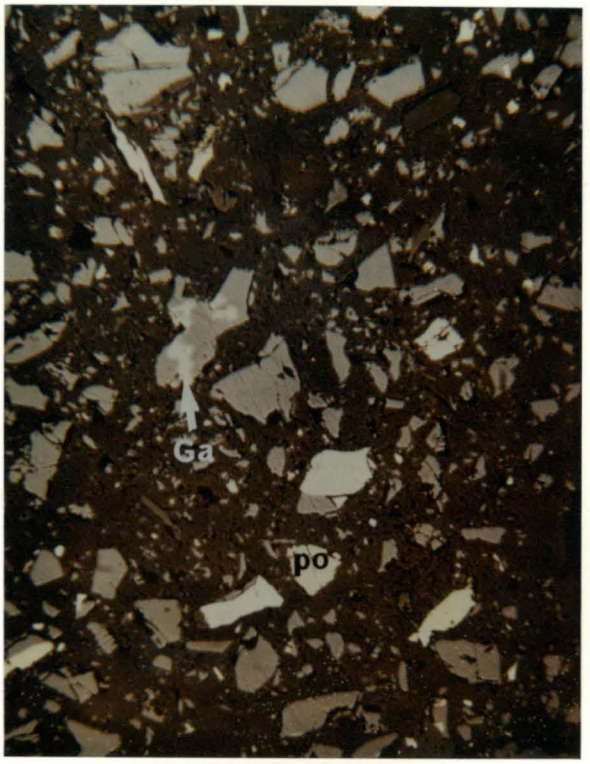

0.000KEV =0
0.000
MN-25

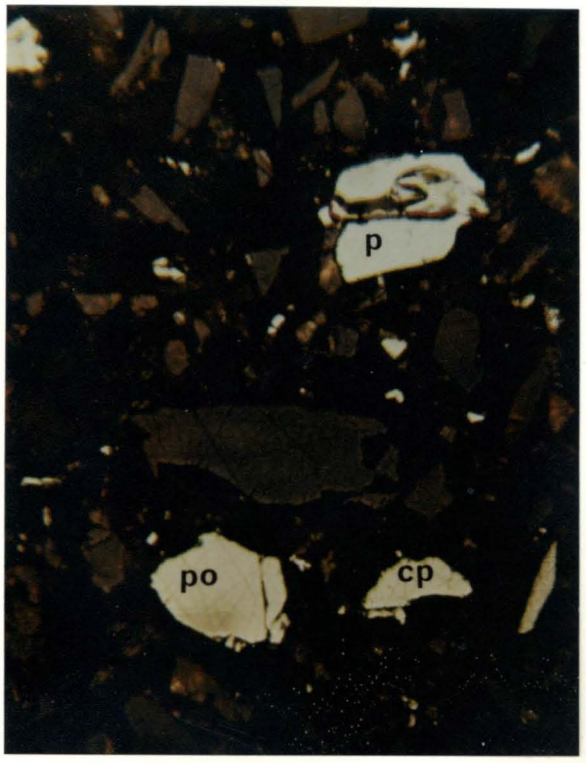
ZINC CONCENTRATE

Sample 2H: particles of sphalerite, pyrite, pyrrhotite, galena and chalcopyrite photographed by using magnifications of 200x (top two photomicrographs) and 500x (bottom two photomicrographs).

Most of the sphalerite grains are liberated. The galena is attached to or enclosed in sphalerite. The chalcopyrite is liberated and associated with sphalerite-galena.


po
p

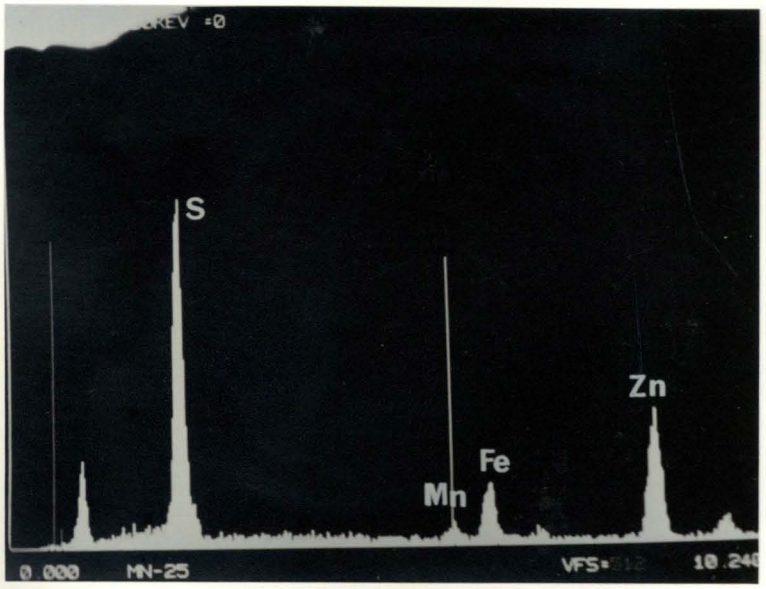

Ga
po

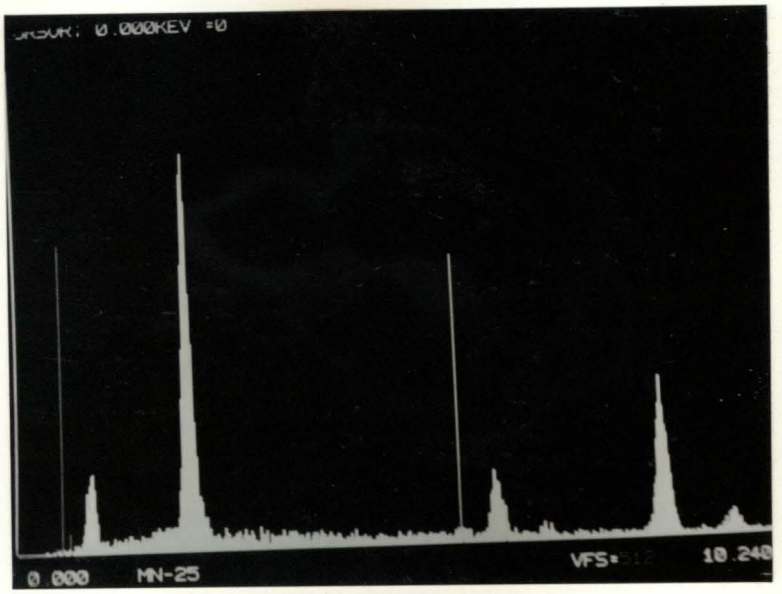

p
po
cp

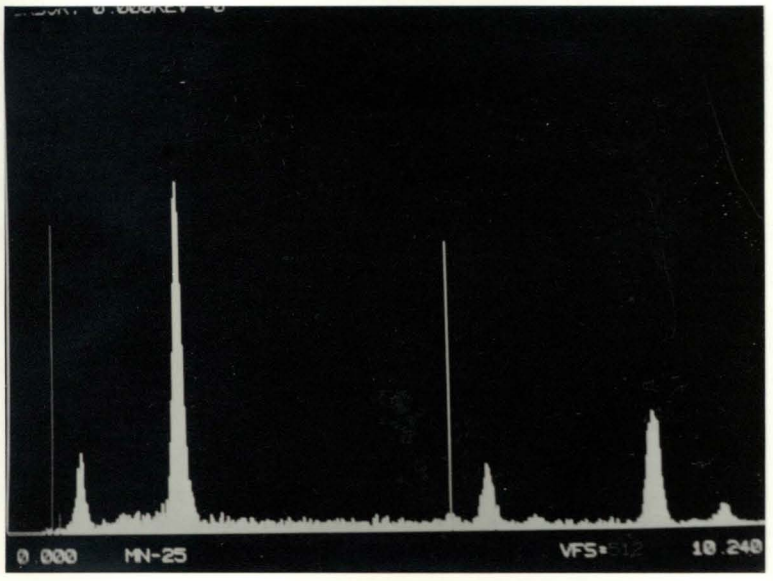

cp
Ga
sl

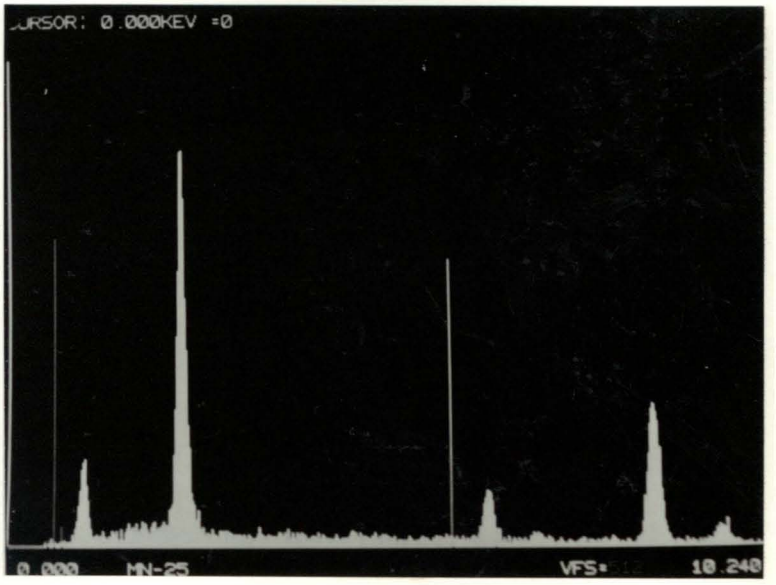
ZINC CONCENTRATE

Sample 2H: x-ray spectra of sphalerite showing minor variable amounts of Mn


S
Mn
Fe
Zn
0.000
MN-25


0.000
MN-25


0.000
MN-25


0.000
MN-25

TAILINGS

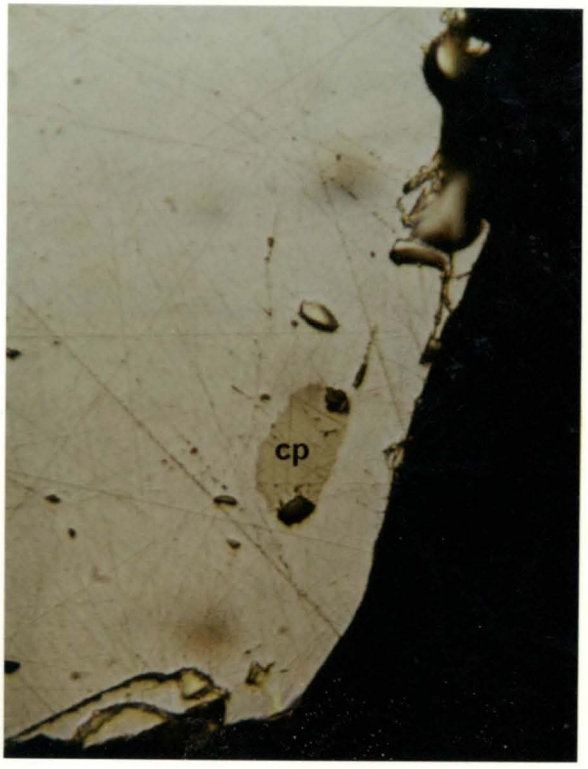
Sample 2A: particles of pyrite, gangue, marcasite (ms) sphalerite and chalcopyrite photographed by using magnifications of 200x (top two photomicrographs) and 1250x (bottom two photomicrographs).

The sphalerite is liberated, the chalcopyrite is enclosed in pyrite.


gn
p


p
ms


sl

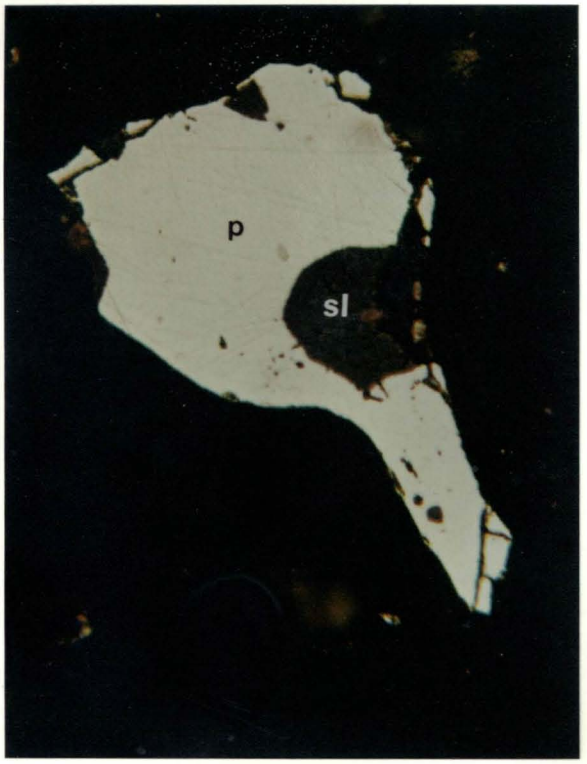

cp

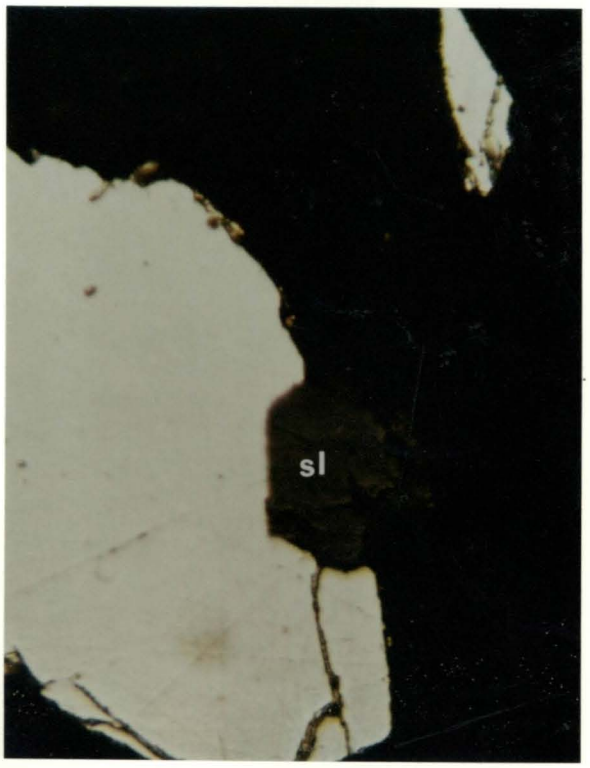
TAILINGS

Sample 2A: particles of sphalerite associated with quartz and pyrite


Qz


Qz

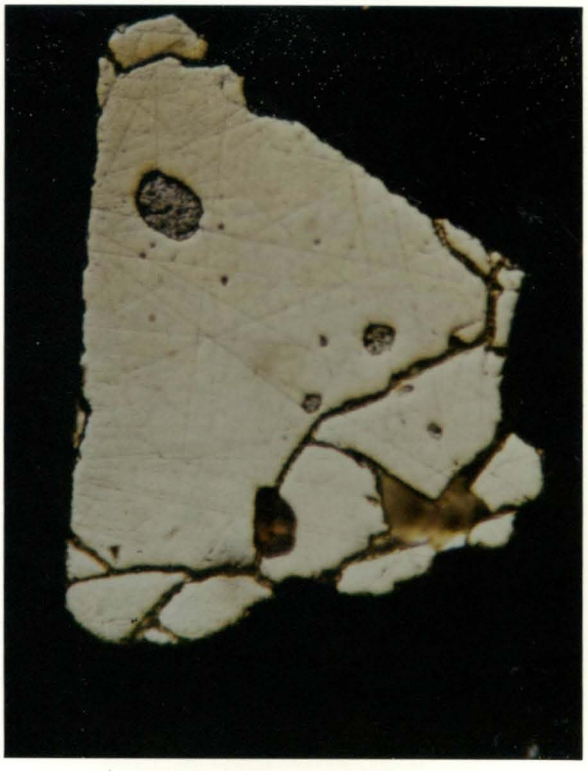

p
sl

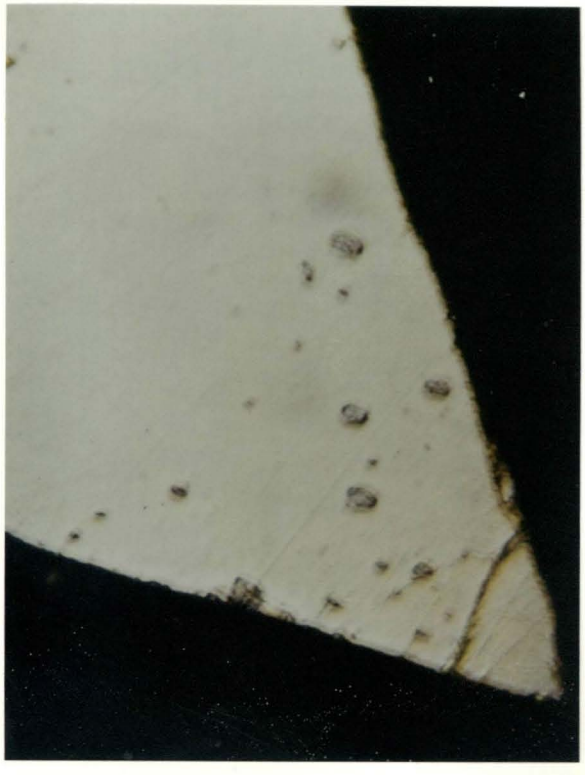

sl

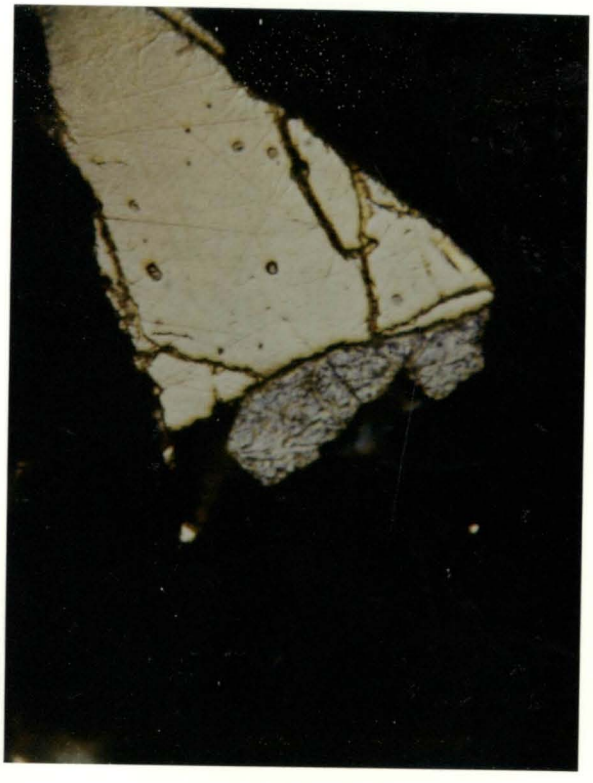
TAILINGS

Sample 2A: particles of galena of different sizes enclosed in and attached to pyrite

Magnification: 1250x



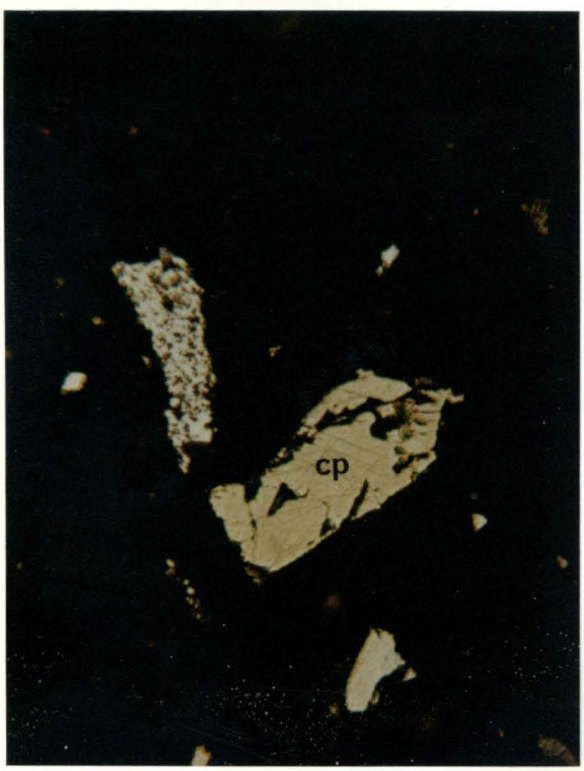


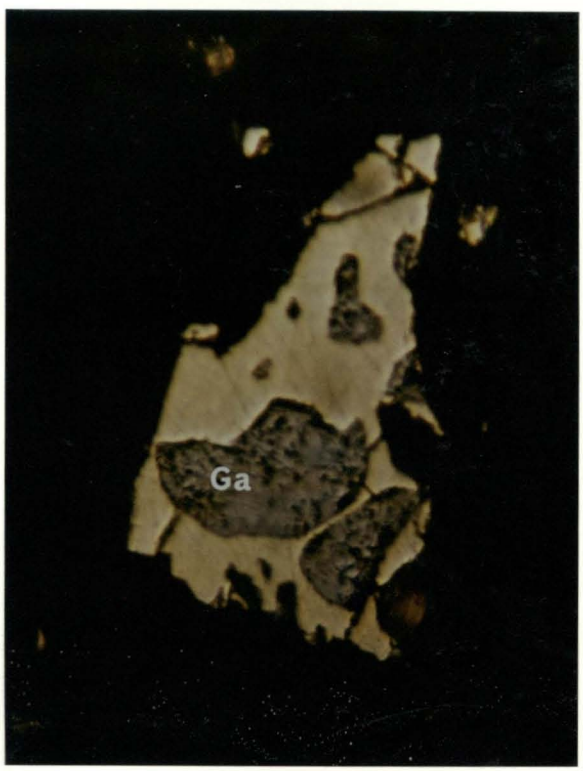


TAILINGS

Sample 2BCD: particles of pyrite, gangue, chalcopyrite and galena photographed by using magnifications of 200x (top two photomicrographs), 500x (bottom left photomicrograph), and 1250x (bottom right photomicrograph).

More than half of the pyrite has a spongy appearence. The chalcopyrite is liberated. The galena is enclosed in pyrite.

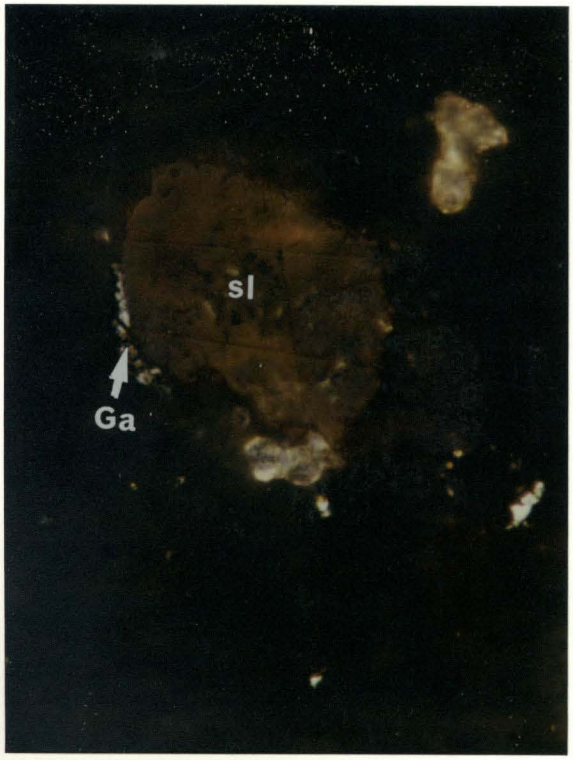

cp

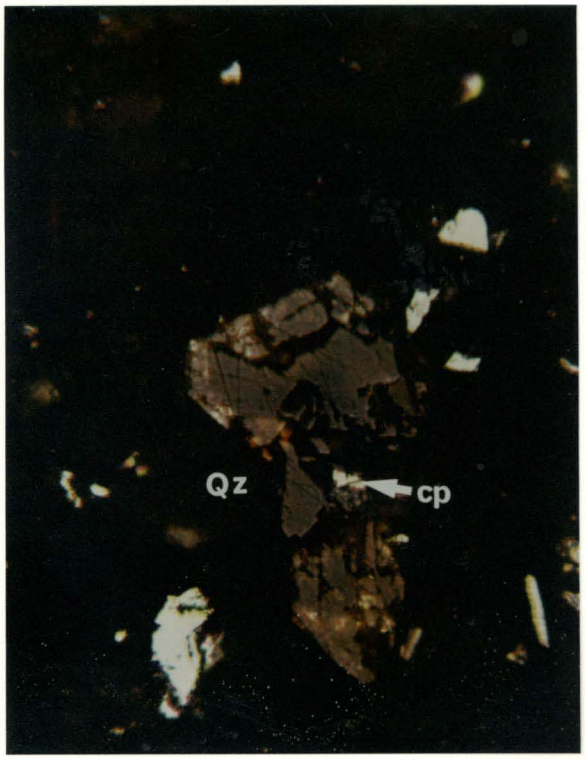

Ga

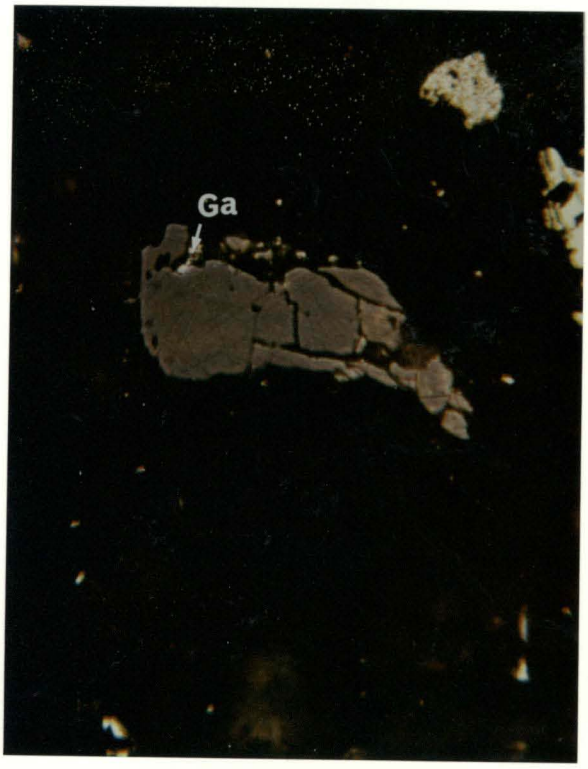
TAILINGS

Sample 2BCD: particles of sphalerite liberated and associated with minor galena, quartz and chalcopyrite

Magnifications: 1250x for the top photomicrographs, 500x for the bottom photomicrographs


sl
Ga


Qz
cp

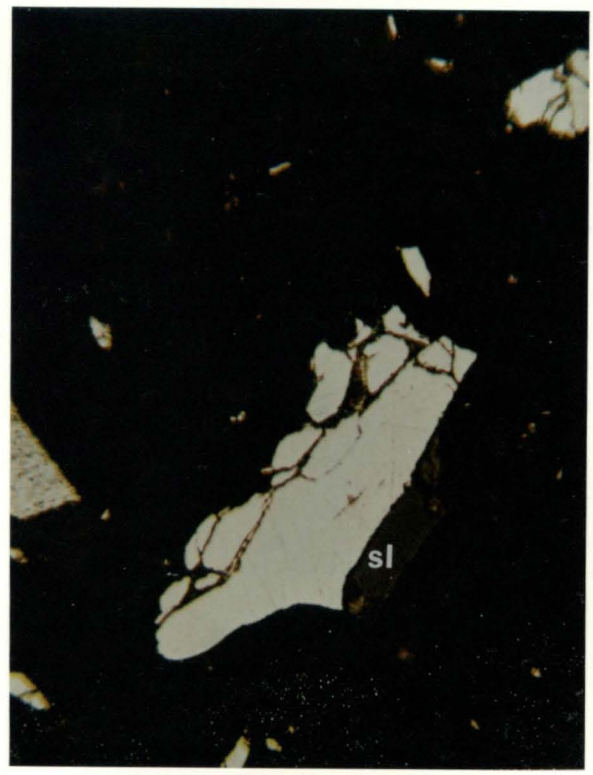

Ga

TAILINGS

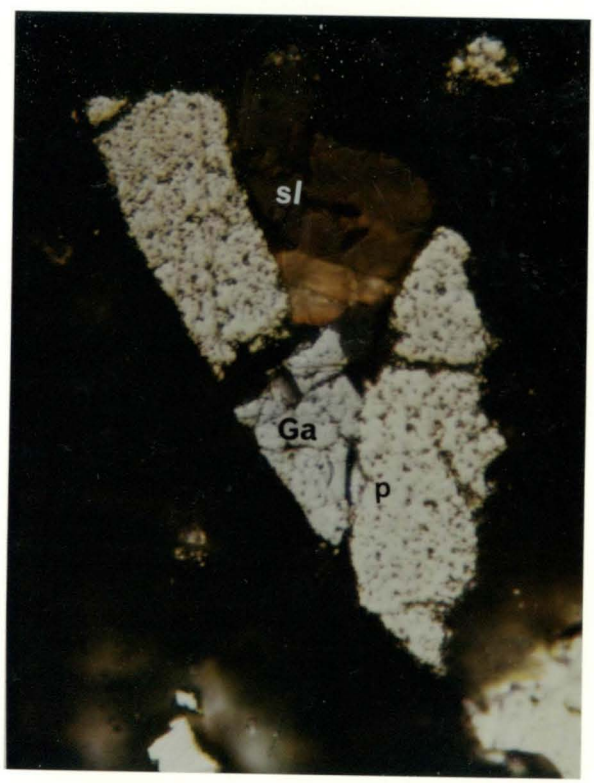
Sample 2BCD: particles of sphalerite associated with pyrite and galena-pyrite

Magnifications: 500x for the top photomicrographs, 1250x for the bottom photomicrographs


p
sl


sl


sl

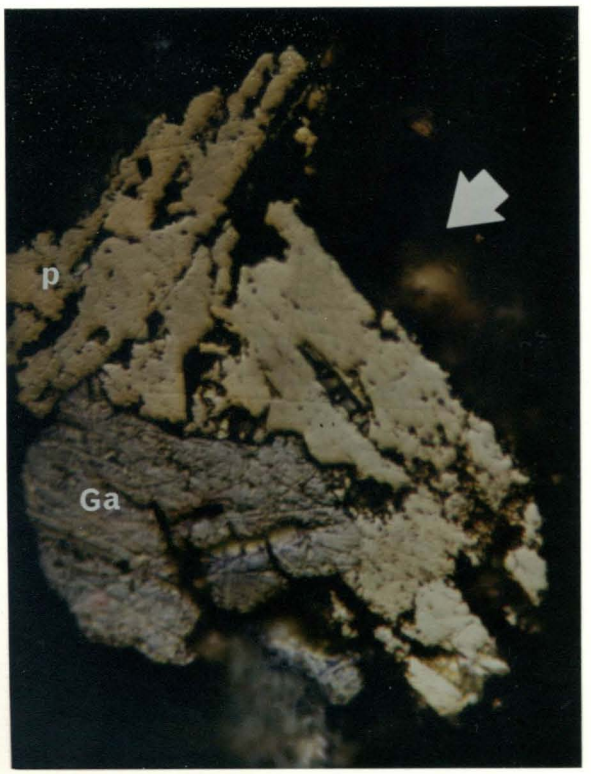

sl
Ga
p

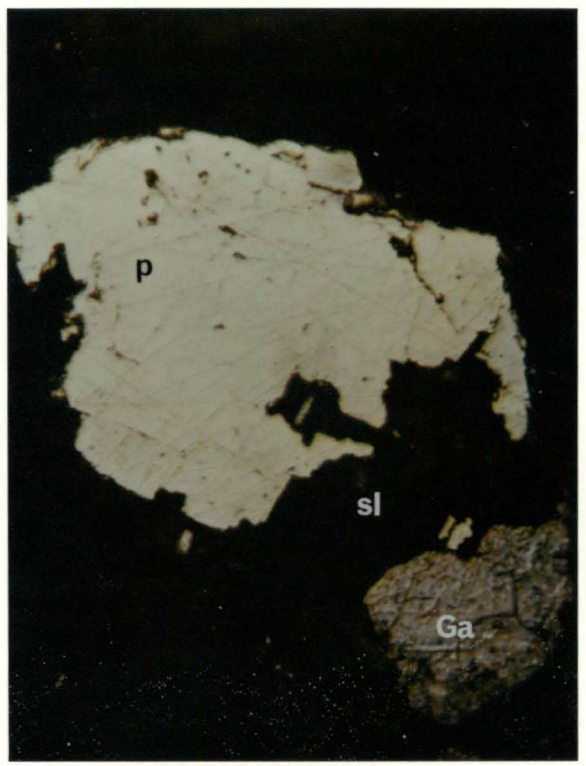
TAILINGS

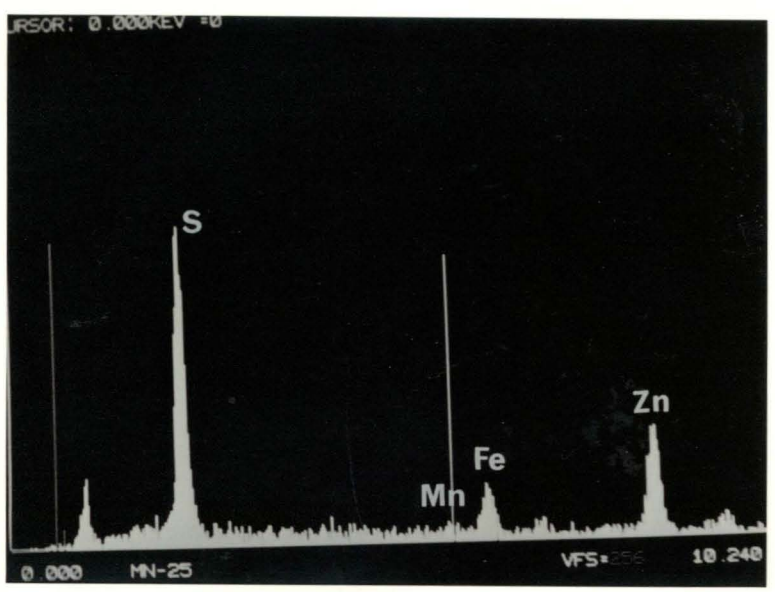
Sample 2BCD: particles of sphalerite associated with galena and pyrite.

The x-ray spectrum of the sphalerite shows minor amounts of Mn

Magnification: 1250x


p
Ga


p
sl
Ga

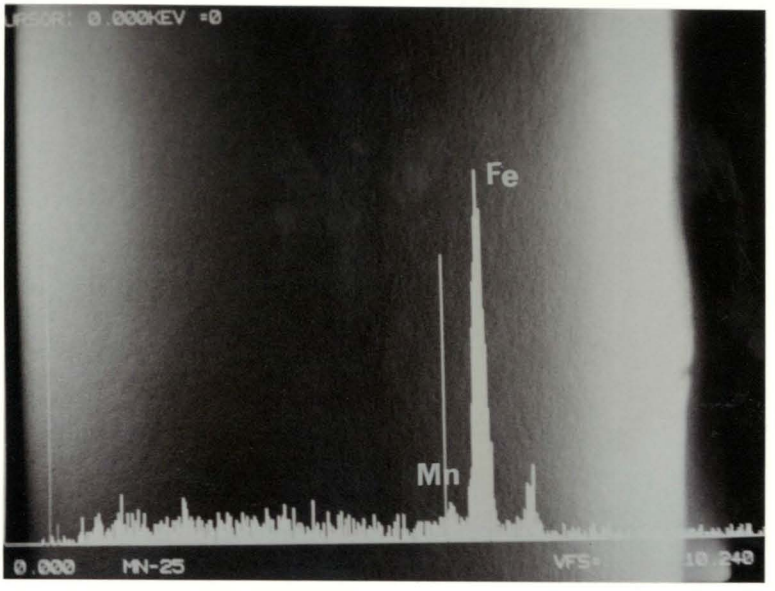

URSOR: 0.000KEV =0
S
Zn
Fe
Mn
0.000
MN-25
10.240

TAILINGS

Sample 2BCD: a composite grain consisting of sphalerite-Fe carbonate.

The x-ray spectrum of the Fe carbonate shows minor amounts of Mn

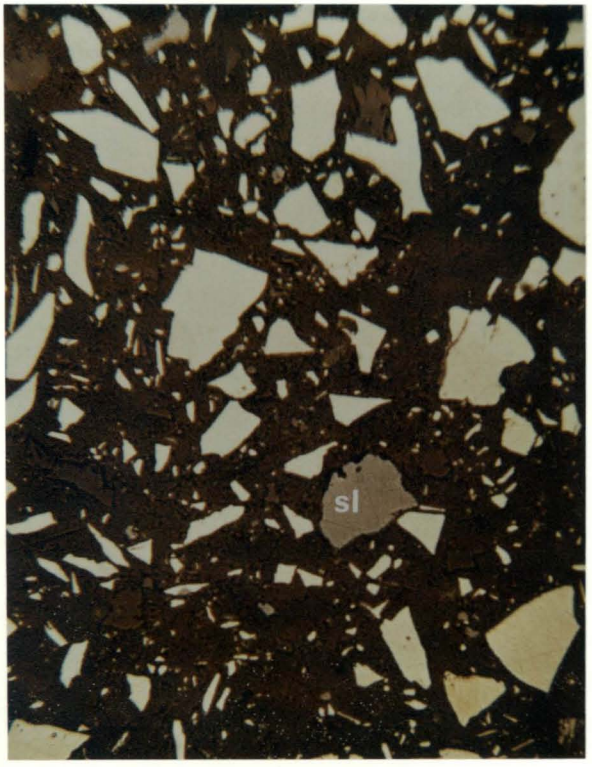

sl

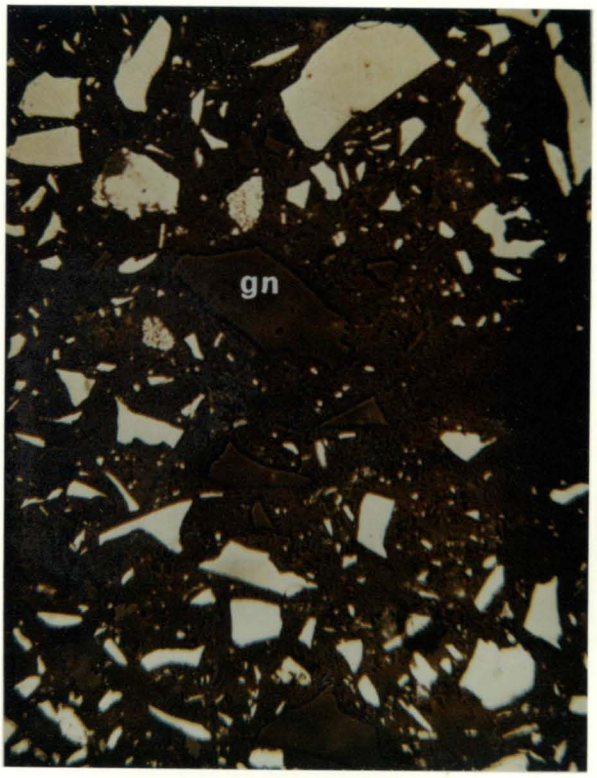

CURSOR: 0.000KEV =0
Fe
Mn
0.000
MN-25
VFS=
10.240

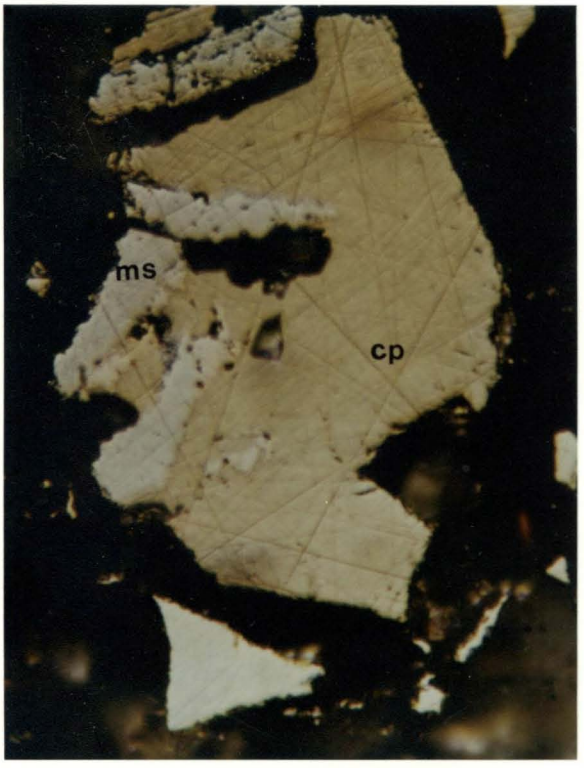
TAILINGS

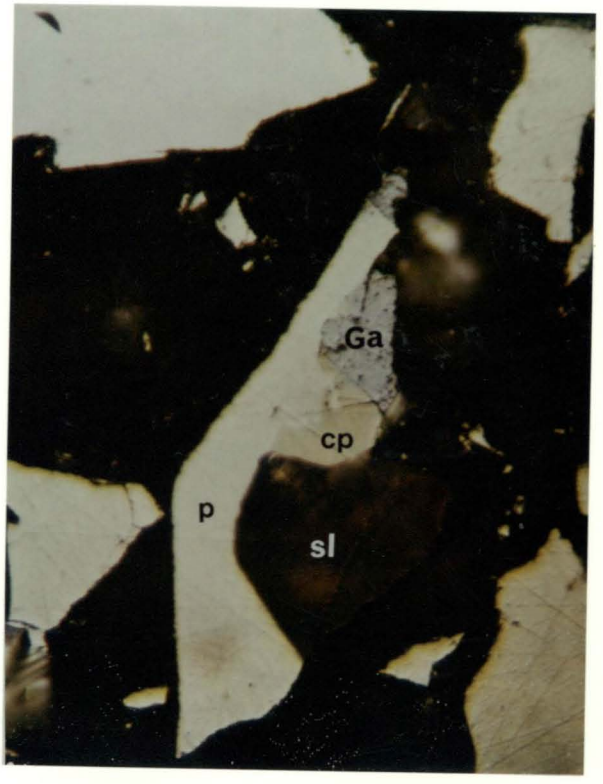
Sample 2EF: particles of pyrite, sphalerite, gangue, chalcopyrite, marcasite and galena photographed by using magnifications of 200x (top two photomicrographs) and 1250x (bottom two photomicrographs.

The sphalerite is liberated and attached to pyrite. The chalcopyrite is liberated and attached to pyrite. The galena is attached to pyrite. The marcasite is enclosed in chalcopyrite.


sl


gn


ms
cp

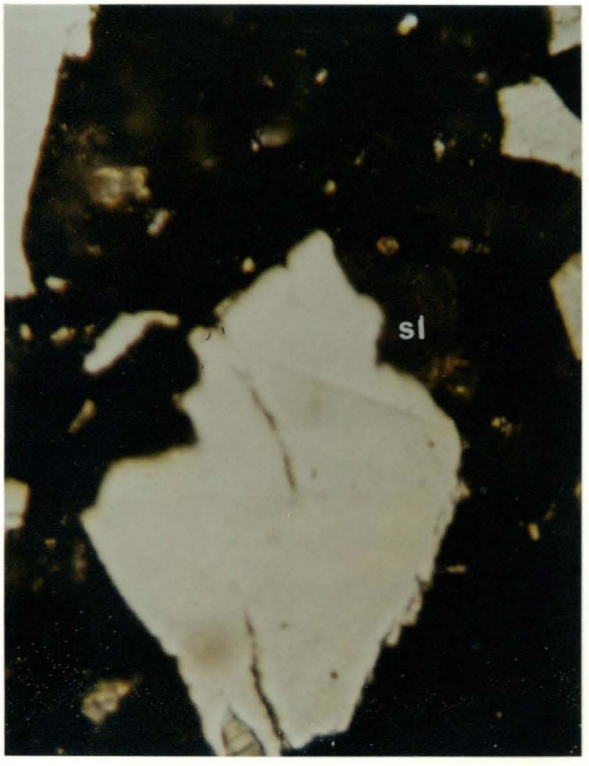

Ga
cp
p
sl

TAILINGS

Sample 2EF: particles of sphalerite liberated, exsolving chalcopyrite, attached to pyrite and attached to galena-pyrite.

Magnification: 1250x


cp

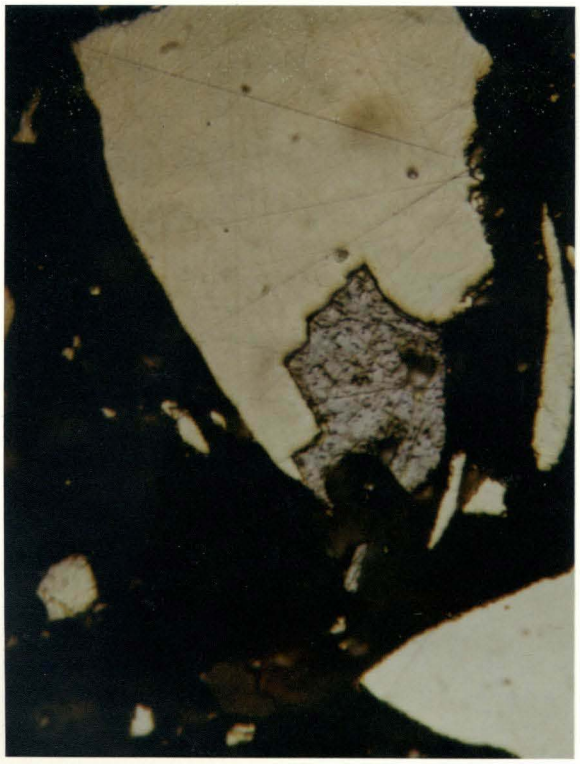

sl

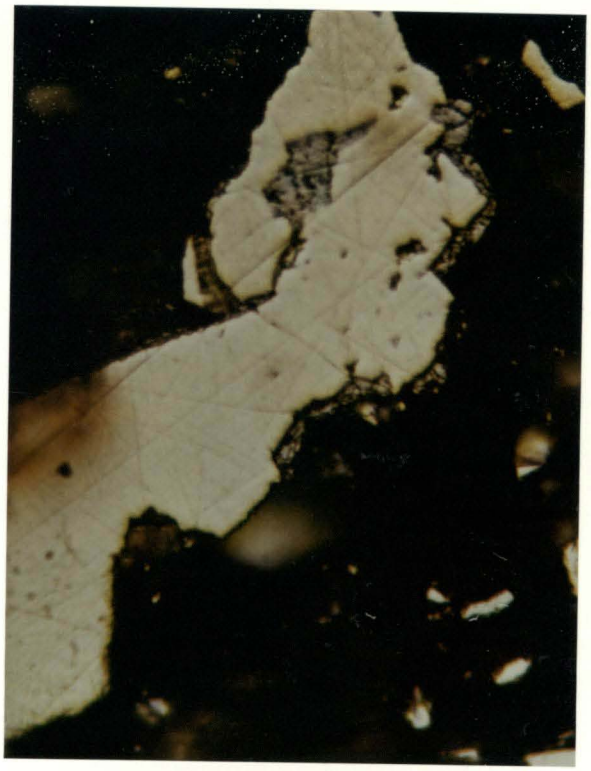

Ga
sl

TAILINGS

Sample 2EF: particles of galena differently associated with pyrite

Magnification: 1250x



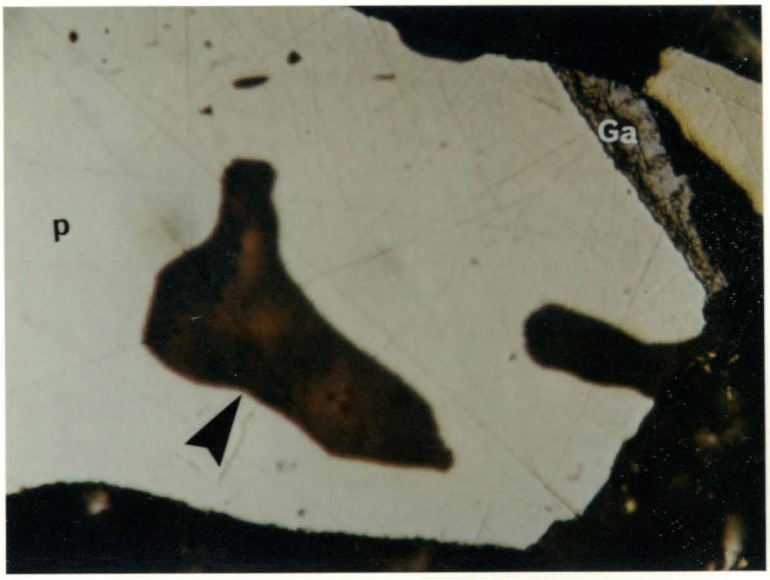


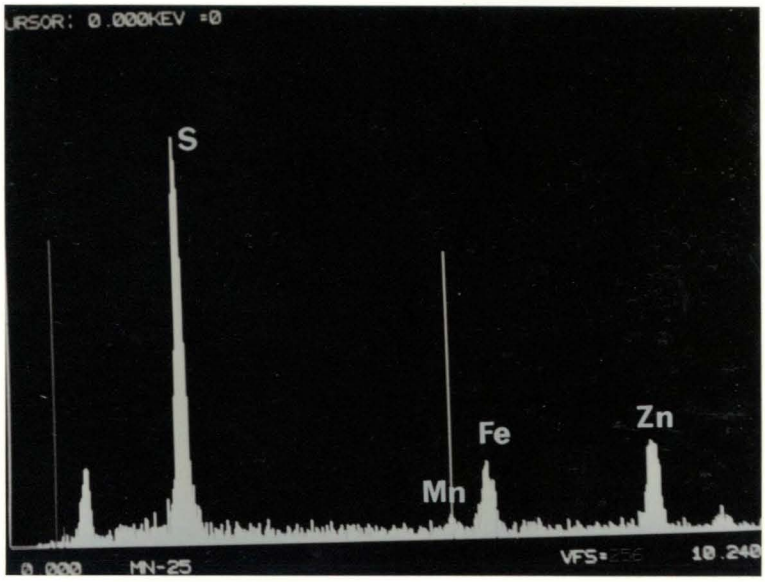
TAILINGS

Sample 2EF: sphalerite (marked by arrow enclosed in and galena attached to pyrite

The x-ray spectrum of the sphalerite shows minor amounts of Mn

Magnification: 1250x


Ga
p

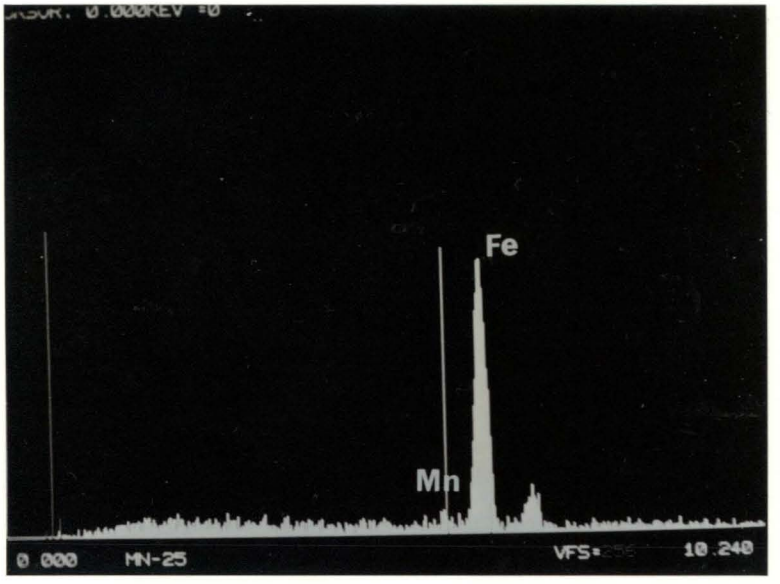

URSOR: 0.000KEV =0
S
Mn
Fe
Zn
0.000
MN-25
10.240

TAILINGS

Sample 2EF: liberated particle of Fe oxide.

The x-ray spectrum shows minor amounts of Mn

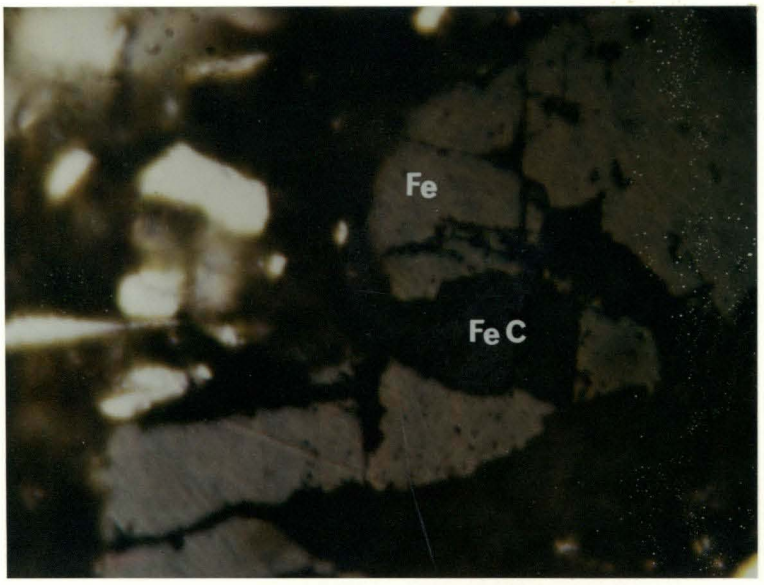
Magnification: 1250x

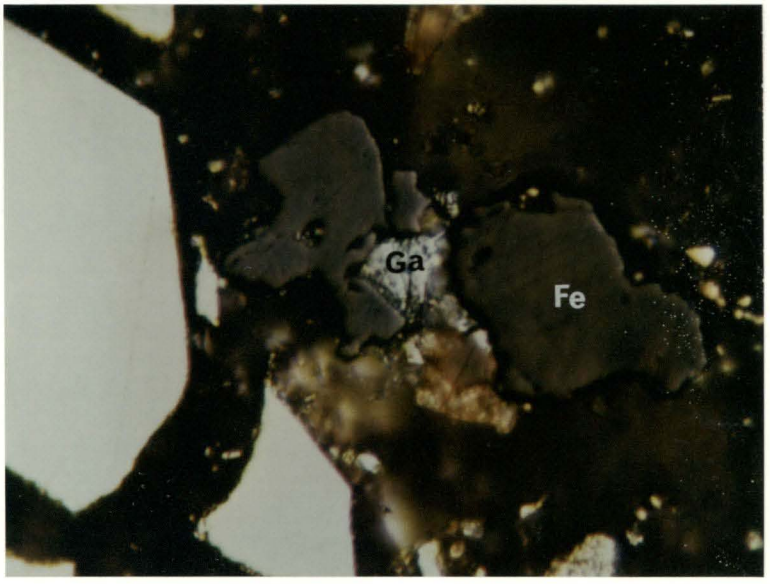

Fe
Mn
0.000
MN-25
10.240

TAILINGS

Sample 2EF: composite particles of Fe oxide (Fe)-Fe carbonate (FeC) and Fe oxide-galena.

Magnification: 1250x

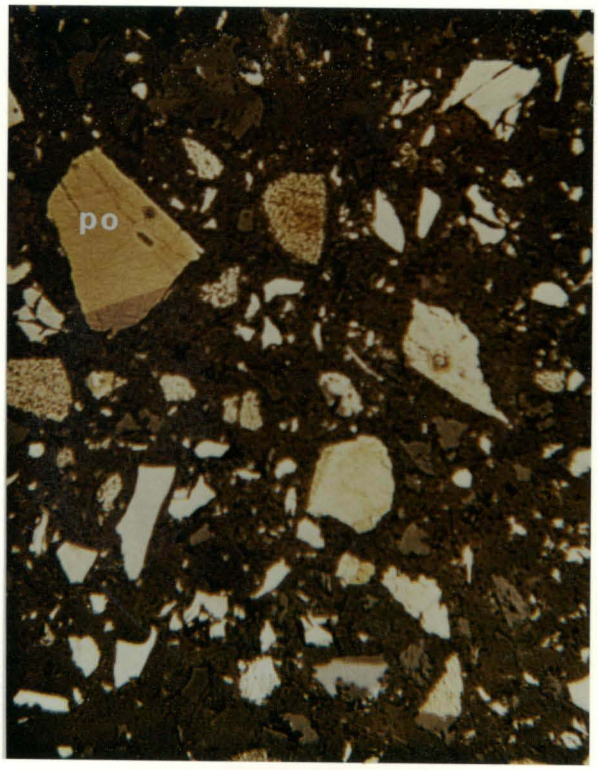

Fe
Fe C


Ga
Fe

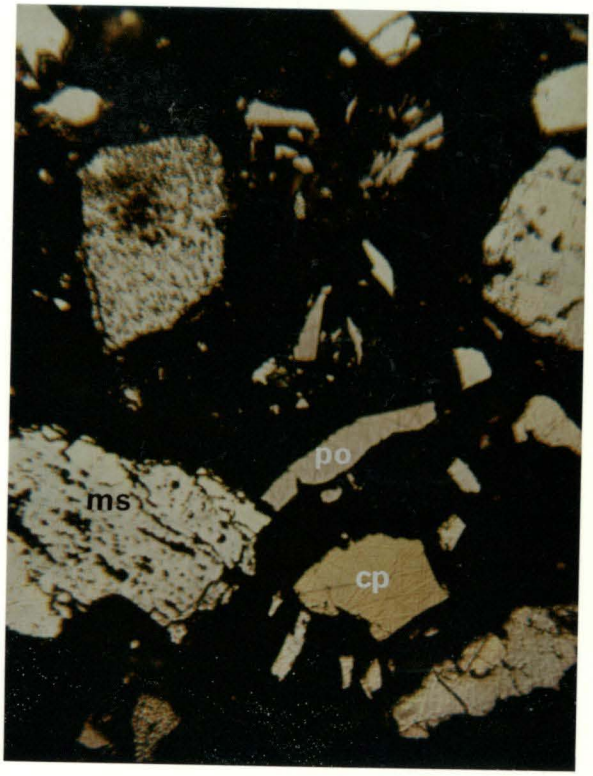
TAILINGS

Sample 2H: particles of pyrite, pyrrhotite, chalcopyrite, marcasite, and gangue photographed by using magnifications of 200x (top two photomicrographs), 1250x (bottom left photomicrograph) and 500x (bottom right photomicrograph).

Much of the pyrite has a spongy appearence. The chalcopyrite is liberated. The marcasite is associated with massive pyrite


po


p

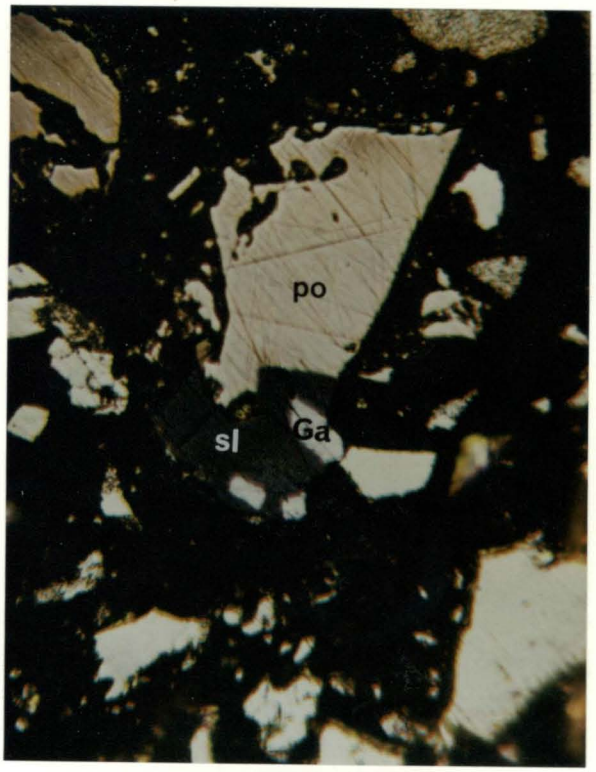

po
ms
cp

TAILINGS

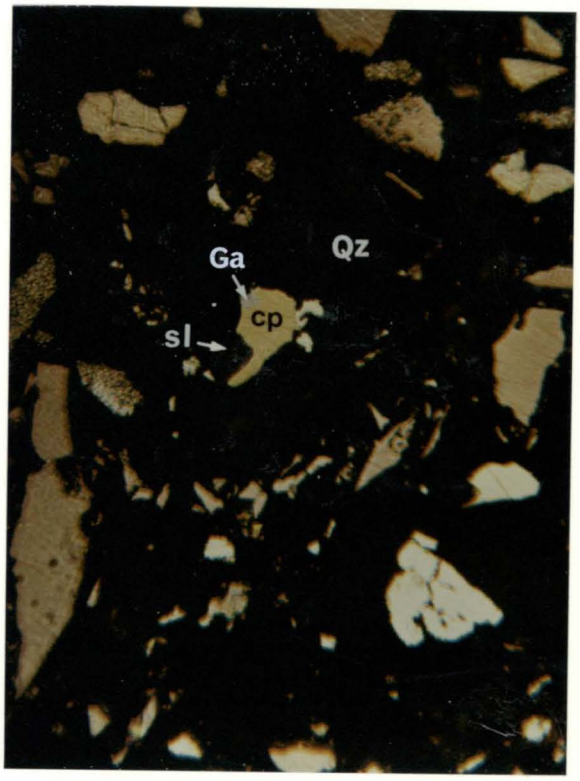
Sample 2H: particles of sphalerite liberated and associated with pyrrhotite-galena, pyrite and chalcopyrite-quartz-galena

Magnification: 500x


sl


po
sl
Ga


sl


Ga
Qz
cp
sl

TAILINGS

Sample 2H: fine particles of galena enclosed in pyrite and quartz

Magnification: 500x


Qz