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ORE PETROGRAPHY OF THE BIG MISSOURI DEPOSIT

NORTHWESTERN BRITISH COLUMBIA

Prepared for Westmin Resources

and

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by

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S U M M A R Y

Mineralization of the Big Missouri deposit occurs in concordant layers of stockwork breccias and semimassive sulphides. Sulphide mineralogy is dominated by sphalerite and pyrite with lesser amounts of galena and chalcopyrite. Silver occurs in native form, argentite, electrum and freibergite. Gold occurs only in electrum, which has three distinct habitats: as minute grains entirely enclosed by sphalerite, as relatively coarse grains along sulphide grain boundaries; and as variable sized grains within gangue. While electrum displays an affinity for sphalerite, the other silver minerals show strong affinities for chalcopyrite and galena. Electrum compositions are generally equal parts of silver and gold with slight variations depending upon occurrence. Other minerals observed include: pyrrhotite, chalcocite, barite and anglesite. Trace metals found in sulphides consisted only of gallium and bismuth within galena.

Sulphide textures were not particularly diagnostic with respect to ore genesis and ranged from euhedral disseminations to irregular massive polymetallic aggregates. Most sections indicated variable degrees of remobilization and/or modification of original sulphide textures. Gangue mineralogy was primarily quartz with lesser amounts of carbonate, sericite, oxides and carbon. Carbonate compositions were various solid solutions between calcium, iron and manganese end members. Gangue textures indicate shallow, open space deposition with minor modification by later strain.

Three or four mineralization types were recognized on the basis of mineral assemblages and abundances. Up to three types were observed

within a single zone. Mineralization types require chemical and statistical verification before their significance (if any) is known.

Textures, mineralogy and morphology of mineralization are compatible with an epithermal-synvolcanic origin. A spatial and genetic relationship with Silbak Premier (or a similar deposit) is strongly suspected.

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1 INTRODUCTION

1.1 Scope and Purpose

The Big Missouri deposit, in northwestern British Columbia, is an unusual occurrence of stratabound precious metal mineralization within the Cordillera. Silver and gold minerals and associated base metal sulphides occur in siliceous and carbonaceous horizons within a fragmental volcanic sequence. The property saw production during the late 30's and early 40's under the operation of Cominco Ltd. Present exploration by Westmin is directed towards the assessment of open pit mining of precious metals. The purpose of this study is to document ore mineralogy and textures as an aid to future geological and metallurgical studies. More specifically, the study has endeavoured to determine the following:

- mineralogy of ore and gangue
- size and distribution of precious metal minerals and their relationships to base metal and gangue minerals
- textural relationships and processing properties
- presence and distribution of significant (economic or genetic) elements not routinely checked for

The results and interpretation of this study should contribute to the overall understanding of the deposit and its origin, serving as an aid to exploration and development.

1.2 Location, Access and Geological Setting

The Big Missouri property is located 25 km northeast of Stewart, British Columbia. Access to the property is provided by the Granduc road, from Stewart to the Silbak Premier mill site, and then by rough road to the exploration camp near Hog Lake. Topography of the region is rugged, being situated within a deeply dissected area of the Coast Range.

General geological setting of the property is on the western margin of the Intermontane belt near its contact with the Coast Plutonic Complex. The junction of the Intermontane belt and the Coast Plutonic complex is irregular and defined in this area by the contact zone of Jurassic volcanics and sediments of the Hazelton and Bowser Groups with the Texas Creek pluton. Minerlization is confined within Hazelton Group stratigraphy.

1.3 Methods

Fourteen samples from four zones were selected for study by Westmin geologists. Samples from outcrop or drill core were selected to represent material which would be processed in a possible mining situation. Up to three polished sections were cut from each specimen, depending on homogeneity and mineral distribution, totalling thirty sections. Four of these were polished thin sections for petrographic work. With the exception of thin sections, samples were cut and polished by hand using normal procedures.

Polished sections were studied by reflected light microscopy for textural and mineralogical information. Most sections were also observed under the scanning electron microscope (SEM) with attached X-ray energy dispersive system (EDS). SEM back scattered electron images, where brightness corresponds to average atomic weight of the minerals, are extremely useful for the rapid detection of gold and silver minerals, particularly when grain size is extremely small. This procedure was hampered by relatively large amounts of galena, which has a similar atomic weight as electrum, within the Big Missouri samples. Because much of the electrum in Big Missouri samples could be observed by optical methods, special etching techniques for galena were not employed. The EDS can provide qualitative chemical compositions of minerals down to 1μ in size. This was used to confirm visual mineral identifications and to check for chemical variations within various minerals. The EDS proved extremely helpful in silver mineral determinations as rapid oxidation or tarnish often prevents a reliable optical determination. Chemical compositions for minerals determined by EDS analysis are generally accurate to ±10%.

1.4 Property Geology

Mineralization of the Big Missouri claim group is hosted by a sequence of variably deformed and metamorphosed volcanic flows, pyroclastics, and derived sediments. Breccia, fragmental and clastic textures predominate and volcanic compositions vary from andesite to dacite (Galley, 1981). The stratigraphic section has been interpreted by Galley (1981) as a homoclinal sequence, younging from east to west, of variably coloured tuffs, which grade into mixed andesite tuffs and flows, followed by basaltic andesite flows and tuffs. Mineralization occurs primarily in one to three 'chert' and 'chert-limestone' layers within the mixed, andesite tuffs and flows. The section is unconformably overlain by younger Bowser Group sediments to the east. Irregular plutonic contacts lie just west of the property area. Groves (1971) erroneously mapped the entire section as multicoloured mylonites, cataclastites and schists derived from the Hazelton Group.

Metamorphic and deformation textures of the property rocks are enigmatic. Some units appear fresh and relatively undeformed while others display greenschist facies mineralogy and two or more penetrative cleavages. Two intersecting foliations, discordant to bedding (Galley, 1981), are observed in rocks on Dago hill. Neither of these foliations appears to be oriented relative to the nearest intrusive contact. Folding is evident in the overlying Bowser sediments but has not produced axial plane cleavage. Hazelton rocks elsewhere in the region are, for the most part, undeformed. The positions of Grove's cataclastite zones relative to the intrusive rocks does not support his conclusion (1971) that these zones are directly related to plutonic emplacement. The possibility that the cataclastite zones mapped by Groves represent a complexly faulted (and sheared) mosaic of two or more rock packages with differing geological histories should be considered. Juxtaposition of previously unrelated Hazelton rocks by thrust faulting has been documented in the central Coast Range (Van der Heyden, 1982). Tectonic mixing of stratigraphy may, or may not, be significant to mineral exploration.

2 MINERALIZATION AND MINERALOGY

2.1 Mineralization

Two types of mineralization are present on the Big Missouri property: 1) discordant quartz and quartz-carbonate veins carrying base metal and silver minerals and; 2) concordant quartz and quartz-calcite horizons carrying both massive and disseminated base metal sulphides with associated silver and gold minerals. Veins are a later feature, and only carry gold where they cut conformable mineralization. Only the latter type was investigated in this study.

Four examples of conformable mineralization were examined. A description of the mineralogy and textures from each zone is given in the following sections. All of the zones have some mineralogical and morphological features in common. Sulphide minerals vary from massive to disseminated (60 - 5%) and are predominately pyrite and sphalerite with lesser galena and chalcopyrite. Precious metals values are all contained in electrum, argentite, native silver, and freibergite. Rare occurrences of pyrrhotite, chalcocite, barite, anglesite and cerrusite were also observed. Gangue minerology is primarily quartz with minor carbonates, muscovite, oxides and carbon. Most of the rock samples display stockwork type breccia textures with sub-rounded to angular fragments in a gangue-sulphide matrix. Sulphide textures are quite variable and have been modified by later thermal and/or tectonic events. No distinctive genetic features, such as sedimentary type textures, were observed.

I worry about paragenesis!

% volume of section

Argentite

ZONE	SAMPLE	SEM'D	Sp%	Py%	Ga%	Cp%	E	Ag	Arg	Fg	Other	%FeS in Sp	Carbonate Composition	
Province	PZ-1a	Y	13	13	4	5						4		
	PZ-1b	Y	20	8	3	2				t		2		anglesite
	PZ-2a	N	7	11	1	2								
	PZ-2b	Y	6	7	4	1					Cc,Agl	3	Ca	
	PZ-3A	N	11	14	5	2								
	PZ-3b	N	·17	15	9	5								
	PZ-3c	Y	23	9	4	6					Cc	2		
	PZ-2c *	Y	10	10	2	2						3		
S-1	SZ-1a	Y	10	24	1	3	t					1		
	SZ-2a	Y	9	30	3	2	t					4-9		
	SZ-2b	Y	10	10	1-2	1	t +					0		
	SZ-3a	N	10	3	1	1								
	SZ-3b	Y	22	3	1-2	1-2	t					10	$Ca_{.9}Mn_{.1}$	? high
	SZ-4 *	Y	2	1	2	1								
Martha Ellen	MEZ-1a	Y	23	4	t	2				t		7	$Fe_{.7}Mn_{.3}$	
	MEZ-1b *	Y	2	4	t	t						7	$Ca_{.8}Mn_{.2}$	
	MEZ-2	Y	50	5	t	3					Ba, Po	7		
	DZ-1a(2)	Y	9	17	4	1	t ++							
	DZ-2a	Y	2	13	1	1	t +					0	$Ca_{.6}Fe_{.2}Mn_{.2}$	
	DZ-2b	Y	15	50	1	t	t ++							
	DZ-F1	Y	8	7	1-2	2		t	t			0	$Ca_{.5}Fe_{.5}$	
Dago	DZ-F2	Y	3	5	1	1	t	t	t				$Ca_{.6}Mn_{.4}$	
	DZ-3Fa	Y	6	10	2	24					Cc			
	DZ-3Fb	Y	20	7	13	12	t	t						
	DZ-4a	Y	-	6	t	-	t							
	DZ-4b	N	t	12	t	-								
	DZ-4*	Y	t	4	t	-								
	Dago Hi-Grade (2)	Y	5	4	3	1		.1%	.1%			0	$Fe_{.1}Ca_{.1}$	

* Indicates polished thin section.

(2) Indicates two sections from same surface.

Table 1. Summary of petrographic data for sulphide group minerals.

2.1.1 Province Zone

The three samples (seven sections) from the Province Zone are ~~both~~ mineralogically and texturally similar. Rocks are sulphide rich and have fine to coarse fragmental textures with ~~occasional~~ Local distinctive ~~banding~~ Layering. Apart from sulphides, rocks are mostly silica; either as sulphide associated quartz or as highly silicified lithic fragments. Sulphide rich bands cut across earlier quartz veinlets. Sample 2 contains numerous thin bands and clots of black material that is tentatively identified as carbon. ? carbon absent Quote

All of the sulphide minerals are closely associated with each other and there is a tendency to complex inter/overgrowths. Pyrite, which commonly makes up 10% of the rock, occurs in medium to fine, subhedral grains and linear aggregates. Most pyrite is earlier than other sulphides which enclose or partially replace it. Some pyrite appears to be later as it encloses or enters into irregular intergrowths with other sulphides. Sphalerite (≈10%) occurs in coarse anhedral grains which range to semi-massive aggregates. Chalcopyrite and galena, which average 3 and 5%, respectively, form interstial (ti) fillings or rimlike overgrowths with other sulphides. On occasion either may occur free as large irregular clots.

The only observed precious metal occurrence was a paragenetically late "cauliflower" overgrowth of freibergite on sphalerite and pyrite. There is a strong similarity between PZ-3 and DZ-3F samples.

2.1.2 Martha Ellen Zone

The two samples from this zone are texturally different. Sample 1 is a footwall breccia with coarse (up to 5 cm) fragments of silicified and pyritized andesite set in a sulphide-carbonate matrix. Sulphides consist of coarse subhedral to semi-massive red-brown to black sphalerite and lesser

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pyrite. Fragments are angular to rounded and comprise about 60% of the rock. Sample 2 is a breccia of small (pea size) quartz-pyrite fragments set in a matrix of near massive sphalerite and other sulphides. Both samples have numerous open spaces, possibly due to dissolution of carbonate material.

Mineralogically, the samples are similar. Both have sphalerite dominated sulphide systems with only trace amounts of galena. Chalcopyrite, which forms up to 3% of the rock, occurs mostly within sphalerite as "exsolution" or seriate blebs. Only a few rare, highly irregular grains occur apart from sphalerite. Pyrite forms about 5% of the rock and occurs as either disseminated subhedral grains or fine to medium grained aggregates. Many of the grains are pitted and corroded. Only rarely is there intergrowth with, or replacement by sphalerite.

The semi-massive sulphide rock, MEZ-2, displays strain textures indicated by the wispy, lenticular outline of sphalerite grains and the kink folded cleavage planes (marked by chalcopyrite exsolution). This same section is unique to the entire suite in that it is the only sample to contain pyrrhotite, which is intergrown with "exsolved" chalcopyrite. It is also one of two sections to contain some barite.

amount ?

Freibergite was observed as small (10μ) grains within sphalerite in the footwall breccia. No other precious metal occurrences were observed possibly due to an irregular distribution within the rock or extremely fine grain sizes. Sulphide associated carbonate was manganiferous siderite whereas matrix carbonate was calcite or ferruginous calcite.

constant

2.1.3 S-1 Zone

S-1 Zone samples, although superficially dissimilar, share the common feature of being stockworks of quartz-sulphide and carbonate veins and veinlets. Host lithologies, which are possibly highly altered, are also primarily silica and/or carbonate. Mineralogy is difficult to generalize due to a wide variety of textures and sulphide abundances. Average sulphide concentrations (with range given in parentheses) for the zone are: pyrite 13% (3-30); sphalerite 10% (5-20); galena 2% (1-3); chalcopyrite 2% (1-3). All of the sulphides are closely associated, often intergrown in polycrystalline aggregates along veinlets. Multiple phase crystallization is demonstrated by overgrowth textures. Occlusion of copious amounts of gangue within the suplhides is common.

Silver and gold occur only as electrum, which was abundant and observed in all samples except one. Electrum was strongly associated with sphalerite, but also occurred within galena and along sulphide grain boundaries. Grain sizes varied from tiny (2μ) to coarse (40μ). The gold/silver ratio of the electrum was usually about 1 but showed some variation depending upon the occurrences. Electrum grains within sphalerite had compositions to $Au_{60}Ag_{40}$, whereas grains within galena had the reverse relationship. No other silver minerals were observed so that the overall Au/Ag ratio for the zone could be as high as 1.

continue

2.1.4 Dago Zone

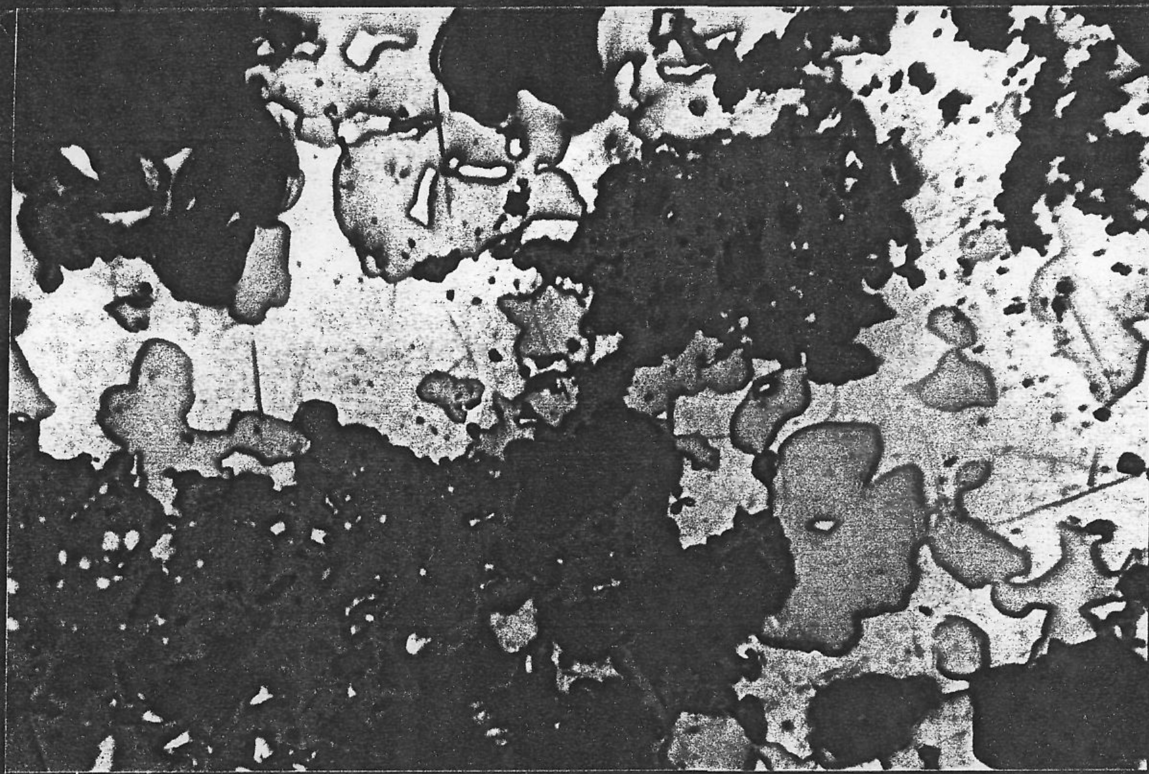
This zone contains the most interesting mineral assemblage as well as the greatest precious metal concentrations. The dissimilarity between rock types necessitates more than a single generalized description.

D-Zone: These rocks consist of highly silicified fragmental andesite (?) with coarse subhedral disseminated to clustered pyrite. On broken surfaces, pyrite grains display well striated faces. Sphalerite and galena occur as finer grained aggregates in distinct bands perpendicular to drill core. Sulphide bands are often separated by thin quartz stringers. Intergrowths are common and any particular phase can be found surrounding other phases. Chalcopyrite is scarce and confined to seriate inclusions within sphalerite which has a negligible iron content.

Precious metal occurrences are restricted to electrum which is common as relatively coarse inclusions in both pyrite and sphalerite. Electrum also resides along sulphide fractures and grain boundaries or free within gangue. The high concentration of electrum of these samples suggests an irregular distribution within the zone. Mineralogically and texturally, this zone is similar to the S-1 zone.

F-zone: (including Dago Hi-grade) These rocks are highly siliceous with dark streaky patches caused by finely disseminated sulphides and carbon. The odd fragment of either grey microcrystalline chert or silicified porphyritic volcanic is still visible. Thin veinlets of iron-carbonate cut through some specimens. These veinlets are in turn cut by diffuse, quartz filled fractures. With the exception of the DZ-3F samples, the sections are sulphide poor relative to the other zones.

Sulphides are dispersed throughout the samples along fractures or veinlets. Grain size tends to be fine although some pyrite and sphalerite grains are coarse. Subhedral pyrite grains are disseminated to clustered and encapsulate considerable gangue and some sulphides. This latter feature may be due to late sulphide growths on corrosion surfaces. Sphalerite varies from anhedral to amoeboid in shape and displays two stages of crystallization: the first with 3-4% "exsolved" chalcopyrite and the second with little or no copper. Galena and chalcopyrite are mostly included in sphalerite but also occur as fine to medium blebs and sinuous grains along fractures. Samples DZ-3F a and b, contain abundant chalcopyrite and exhibit a high degree of sulphide intergrowths.



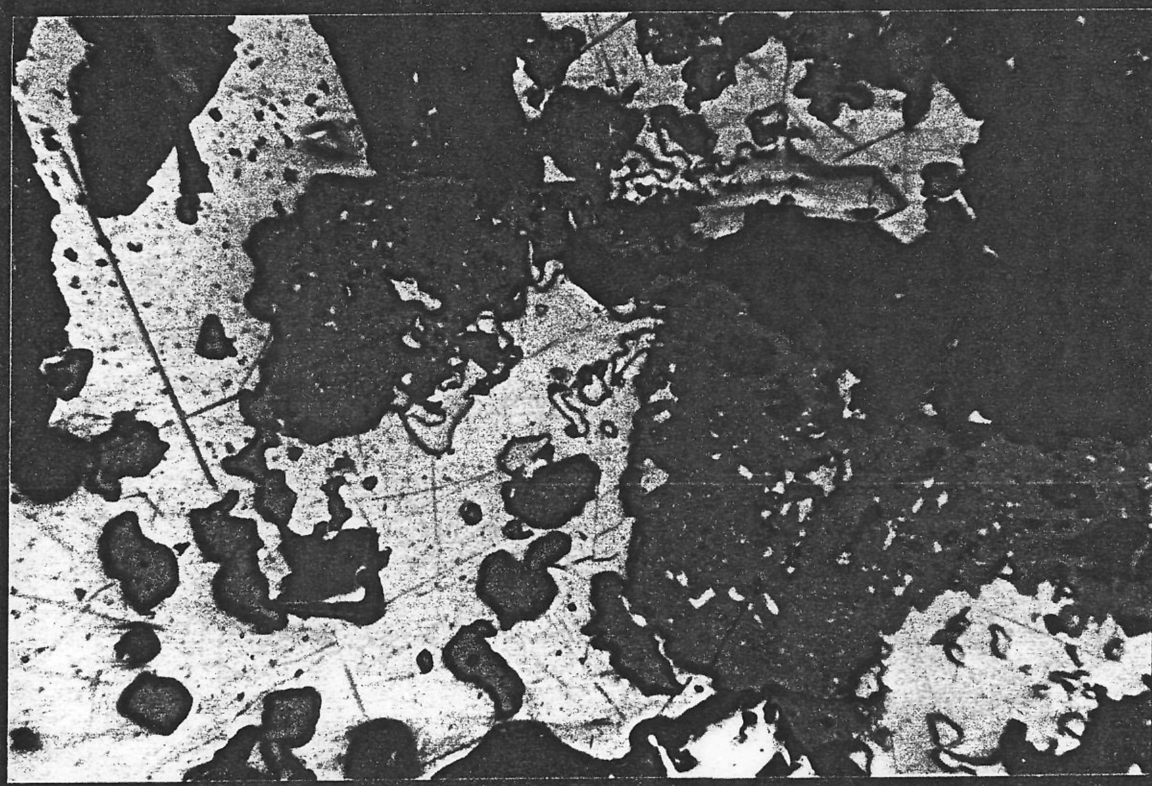
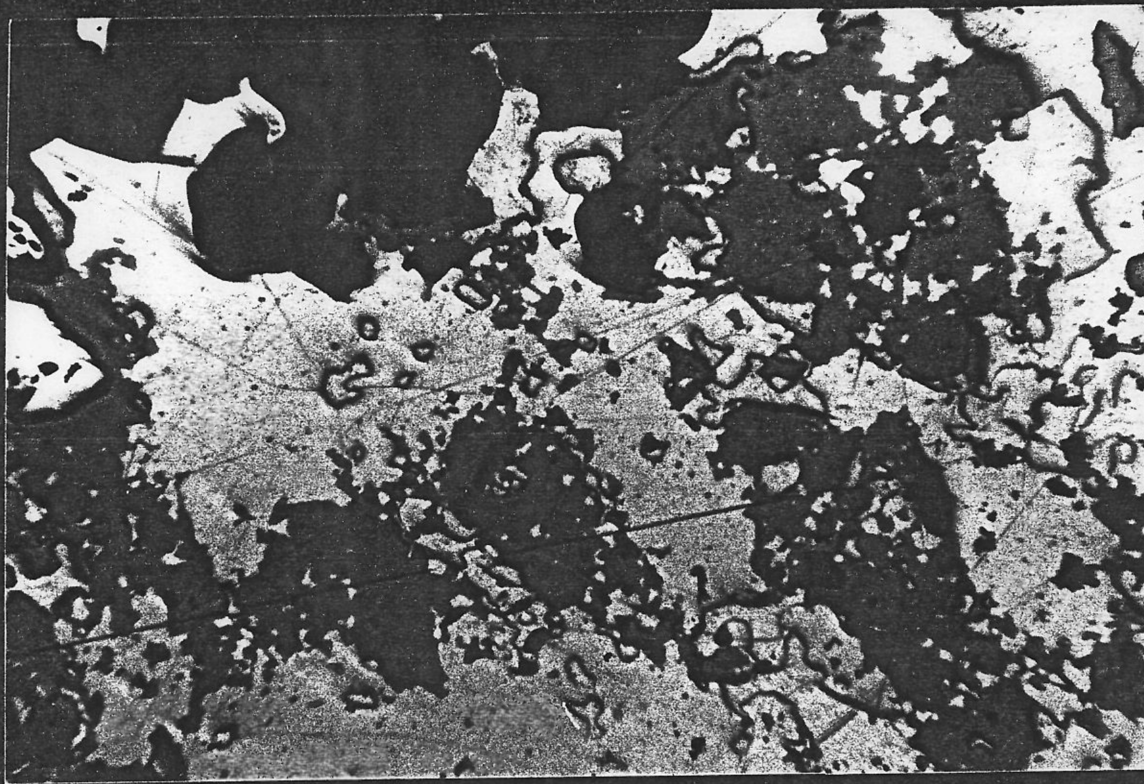


Plate 1 a, b: Galena (pale yellow) - sphalerite (grey) - chalcopyrite (dark yellow) intergrowths in DZ-3Fa (top) and PZ-3b (bottom). Green dots are due to diffracted light in depressions. Note chalcopyrite inclusions in sphalerite. Field of view is 35 mm (40 X).



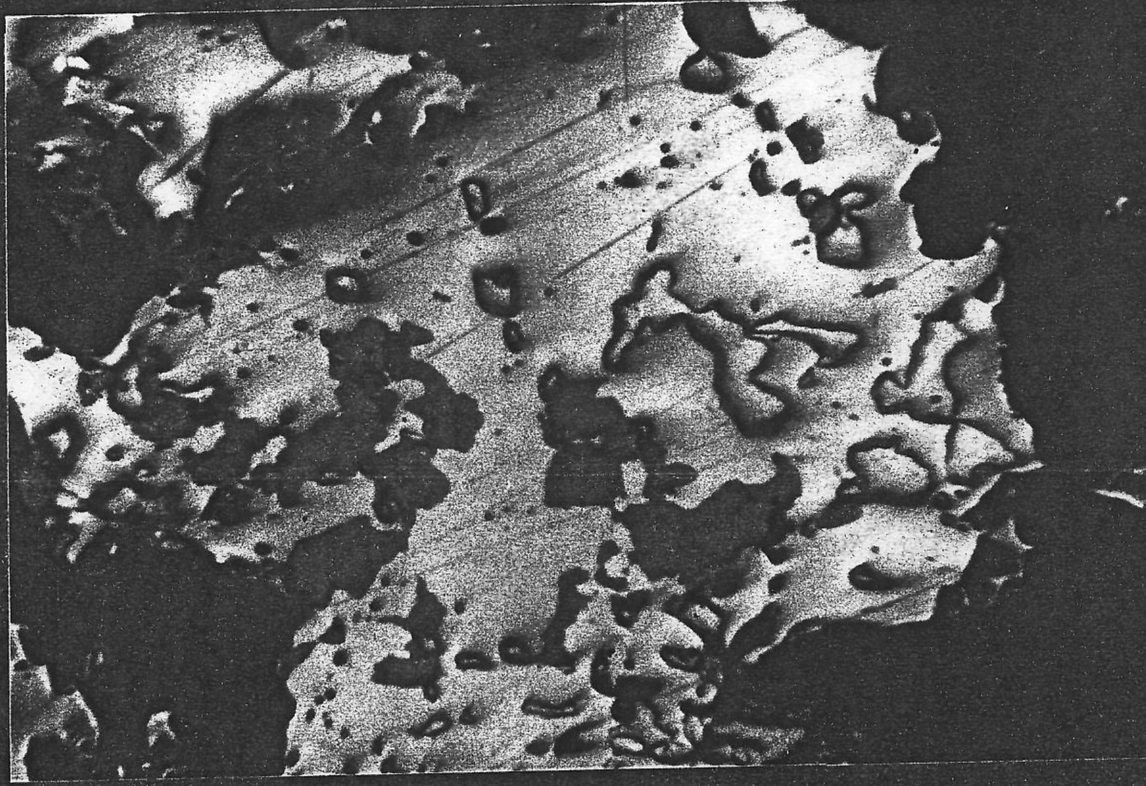


Plate 1 cd: Chalcopyrite-sphalerite-galena intergrowths in PZ-3b (40X) and DZ-3Fa (90X).

Electrum, native silver and argentite are abundant (except in DZ-4) and occur free in gangue, associated with galena and chalcopyrite, or enclosed by pyrite. Coarse electrum grains lie along sphalerite-galena grain boundaries in DZ-3F samples and argentite is intergrown with galena, chalcopyrite and siderite along fracture fillings in Dago high grade samples.

2.2 Mineralogy

The overall mineralogy of the system is quite simple. Similar studies on other deposits utilizing the SEM/EDS have yielded a wide variety of ore and gangue minerals; that was not the case here. With the exception of a few sections, pyrite and sphalerite make up 80% of the sulphide group minerals. Galena and chalcopyrite are minor but can be important locally. Electrum, native silver and argentite account for nearly all the gold and silver content, with only a minor amount of silver contained in freibergite (tetrahedrite). No arsenic was detected in the system and the antimony content is quite small. Where Sb/Cu ratios are high other minerals such as pyargyrite might be found.

Two distinctive precious metal - base metal relationships were observed. There was a strong association of native silver and argentite with chalcopyrite and galena. Gold (as electrum), on the other hand, demonstrated a preference for sphalerite. These relationships appear to be determined more by chemistry than paragenesis and could provide a useful criterion for distinguishing between zones or horizons.

Carbonate compositions were variable. In general calcite and ferruginous calcite were common matrix carbonates while siderite and manganiferous siderite were common sulphide associates. There is at least a weak correlation between manganese bearing carbonates and precious metal mineralization.

siderite.

?! 0.5%?

No magnesium bearing carbonates were found.

Sulphide minerals were relatively pure. Minor amounts of gallium or bismuth were detected in some galena grains. If there is cadmium in sphalerite it is below the EDS detection limits (0.1%). The iron content of sphalerite was quite variable, even within the same sample, and could only be used to characterize zones in a general way. There does not appear to be a good correlation between sphalerite colour and iron content.

The sulphates, barite and anglesite, and other rare minerals (pyrrhotite, chalcocite, covellite, and cerrusite) were extremely minor and restricted in occurrence. All appear to be produced by very localized alteration and are, therefore, not considered overly significant to exploration.

<u>Pyrite</u>: is either the dominant sulphide or only slightly subordinate to sphalerite. In only one case does it occur in lesser quantities than galena or chalcopyrite (DZ-3F). Pyrite occurs in a variety of shapes and sizes, generally as finely disseminated euhedral grains in areas of low sulphide concentrations, or as aggregates of medium to coarse subhedral grains in areas of high sulphide concentrations. Some sections show corrosion and/or partial replacement of pyrite by other sulphides. Only rarely does pyrite exhibit intergrowths with sphalerite. Much of the pyrite crystallized early with later sulphides growing in and around these grains. There are some sections that display late pyrite growth, where small pyrite cubes have grown along the edge of sphalerite grains, possibly indicating a second phase of mineralization. Many sections contain broken and crushed pyrite grains with little evidence of recrystallization.

Sphalerite: content varies from 1 to 50% (average 10%) and, other than pyrite, is the dominant sulphide in the rock suite. Typical textures are medium to coarse grained, subhedral to anhedral aggregates enclosing abundant gangue and other sulphides; although variations from coarse enhedral grains to wispy, invaginated, interconnected, semi-massive aggregates also occurred. Almost all of the sphalerite contained blebs of chalcopyrite arranged along cleavage planes. This texture is commonly referred to as an exsolution feature however, Craig and Vaughan (1981) point out that very little chalcopyrite can be dissolved in sphalerite at temperatures less than 500°C. Since chalcopyrite is paragenetically later than sphalerite, this texture may have arisen through entrapment of copper rich fluids during sphalerite growth. In some cases these "exsolution" blebs have coalesced into coarser inclusions. There are only two examples of copper free sphalerite (SZ-3A, DZ-Hi grade) which may indicate a later phase of sphalerite crystallization. Galena is also frequently included or intergrown with sphalerite, but not in the same manner as chalcopyrite.

The iron content of sphalerite varied across the suite from negligible to 10%. With a couple of exceptions most samples displayed consistent iron content within sphalerite grains although the variance within zones was as great as between zones. In a qualitative sense, the iron content of sphalerite correlates with the sphalerite/pyrite ratio of the section. The color of sphalerite ranged from dark red to black with a single observation of yellow in a polished thin section from the Province zone. Red sphalerites were usually iron rich whereas black ones were variable. No cadmium was detected in any sphalerite grains.

The overall abundance of sphalerite has caused it to be

cc: Alastair Sinclair

associated with most of the other sulphide group minerals; notable exceptions are native silver and argentite. There is a strong association of gold and sphalerite as evidenced by numerous micro inclusions of electrum in sphalerite.

Galena: occurs mostly as inclusions of,or intergrowths with, sphalerite. It is also frequently intergrown with chalcopyrite, both within and apart from sphalerite. Late growth and/or remobilization of galena is indicated by its occurrence as rims on other sulphides, interstitial fillings, and long sinuous growths along fractures. Discreet galena grains, which are not abundant, are usually anhedral except where they are bounded by rhombic carbonate grains. Occasional subhedral grain aggregates occur in some sections.

Galena plays host to electrum grains but shows a preference for argentite and, together with chalcopyrite, hosts native silver. Compositionally, galena contains very minor amounts of gallium and in one instance, bismuth. Secondary growths of anglesite and cerrusite are found peripheral to galena in the Province zone.

Chalcopyrite: is a relatively minor component of the sulphide system. With the exception of the DZ-3F samples, most sections contain from a trace to 5% chalcopyrite with the average at about 2%. A significant portion of the chalcopyrite occurs as "exsolution" blebs or epitaxial growths within sphalerite (which makes volume estimates difficult). "Exsolution" blebs and fine grained inter-growths can form up to 20% of the volume of sphalerite, although 2-5% is the normal amount. Free chalcopyrite varies from small elliptical grains to coarse, ragged and irregular masses. Chalcopyrite often occurs as rims or interstitial fillings around other sulphides.

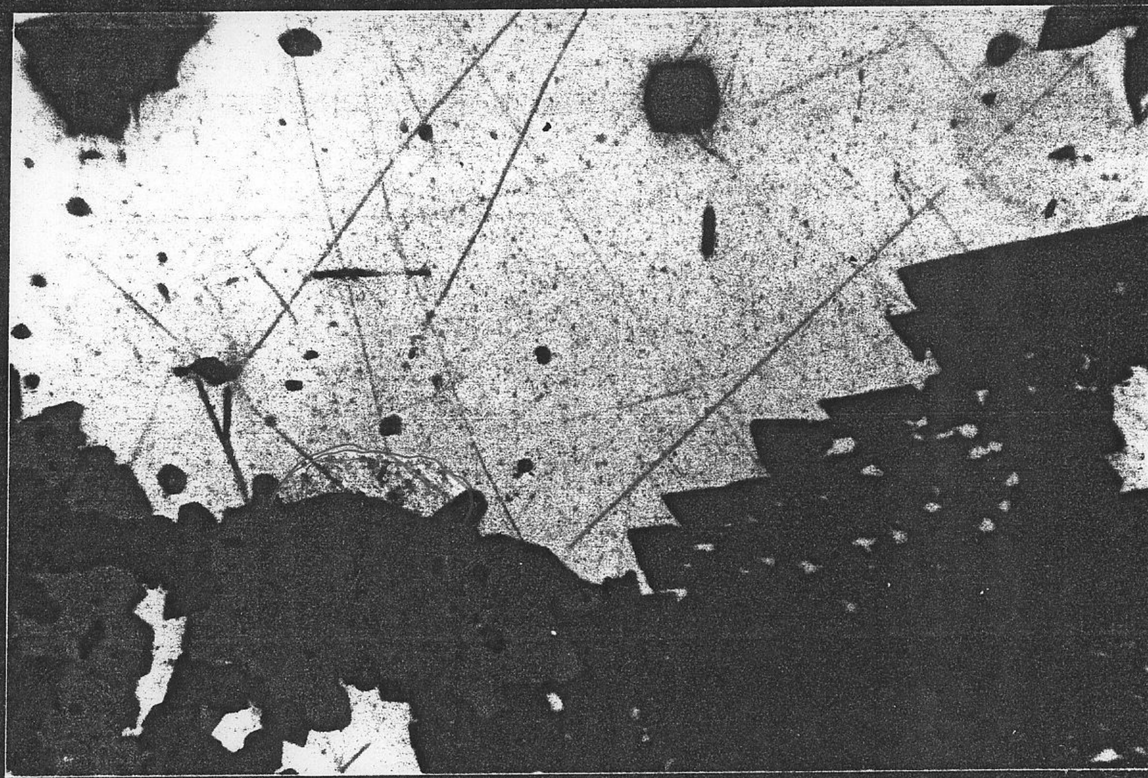
There is a strong association between copper and silver; not only within freibergite but also as chalcopyrite and native silver or argentite intergrowths. This association does not appear to be controlled by the total amount of chalcopyrite present. Chalcopyrite is in contact with electrum but this association is not deemed as significant. A few chalcopyrite grains contain fine blebs or lamellae of chalcocite, presumably due to mild oxidation.

Electrum: is the only gold bearing mineral in the system. It was quite abundant within the S-1 and Dago zones, but was not observed in the Martha Ellen or Province zones. Electrum is anticipated to occur in the Martha Ellen footwall breccia in a similar fashion to the S-1 zone.

The average electrum composition is approximately Au/Ag=1 with slightly higher gold contents within the sphalerite associated grains, and slightly higher silver contents within the galena-chalcopyrite associated grains. There were three distinctive occurrences for electrum which are discussed below.

1) As tiny (1 - 10 μ) rounded grains entirely contained within sphalerite. This occurrence was prominent within the S-1 zone, but occurred in the Dago as well. Volumetrically, the observed grains are a minor constituent of the total gold content but the occurrence may be significant as there is a low probability of observing this type of grain. Most of these grains are likely to report with the zinc concentrate during processing.

2) As medium to coarse elliptical grains along sulphide grain boundaries and interstitial to, or along fractures in pyrite. A major portion of the electrum grains were observed in this setting. Sphalerite-galena or sphalerite-pyrite were the preferred grain boundaries. This occurrence also includes coarse electrum grains fully enclosed by sphalerite or pyrite. Almost allof the grains observed of this type will be free milling



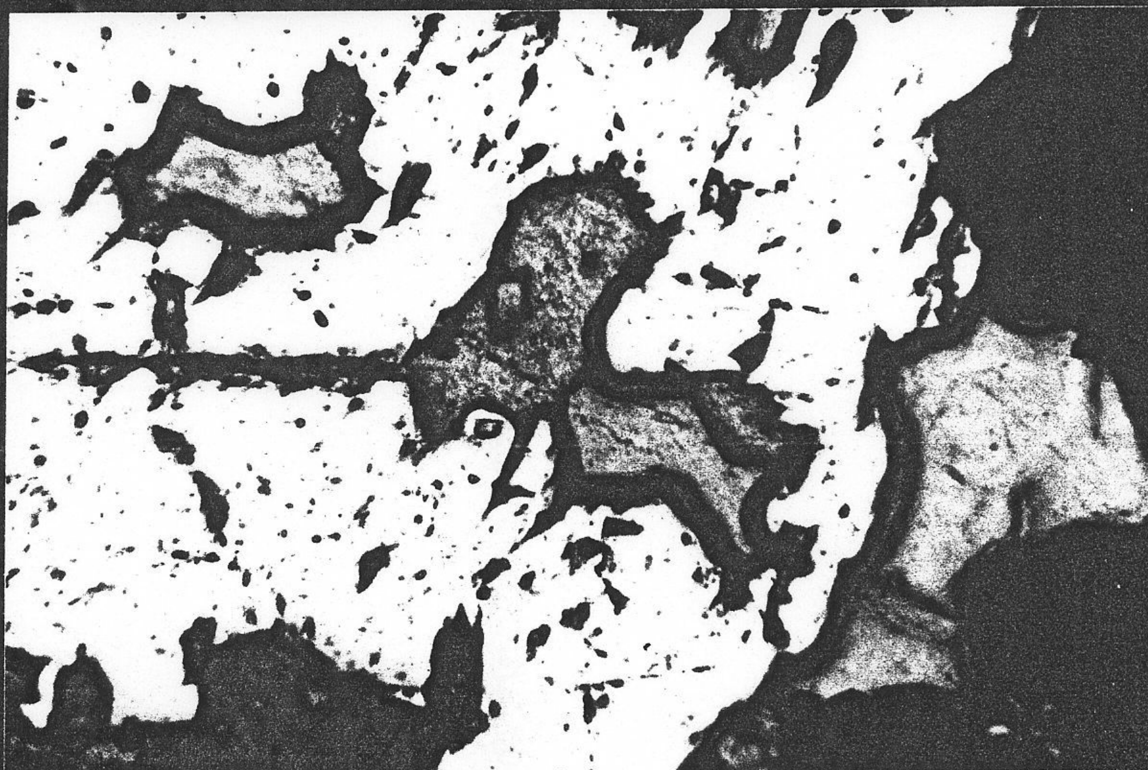
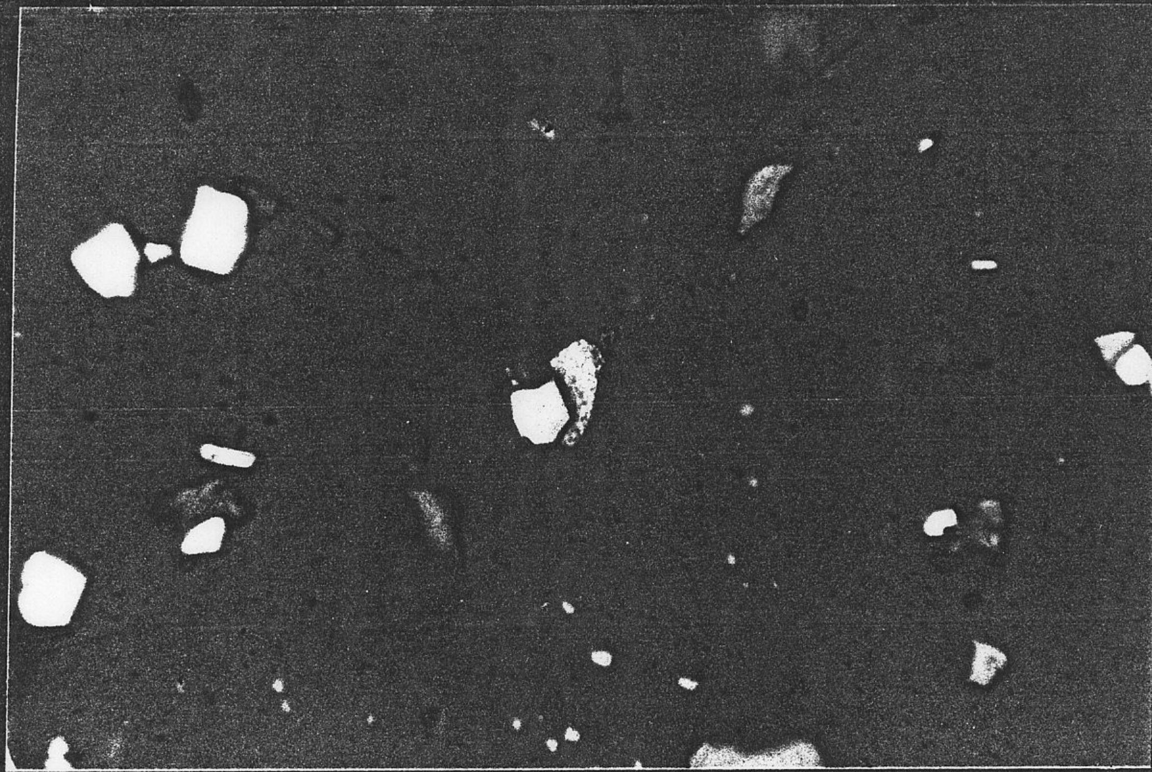


Plate 2 a: Electrum grain along galena (white) and sphalerite (dark grey) grain boundary. Yellow in upper right is chalcopyrite. Note the sharp edge where galena contacts carbonate crystal faces. Electrum grain is 50 μ long and Au ≈ Ag.

2 b: Electrum grains residing in pyrite grain from sample DZ - 1a. Largest electrum grain is ≈ 5 μ. (320 X).



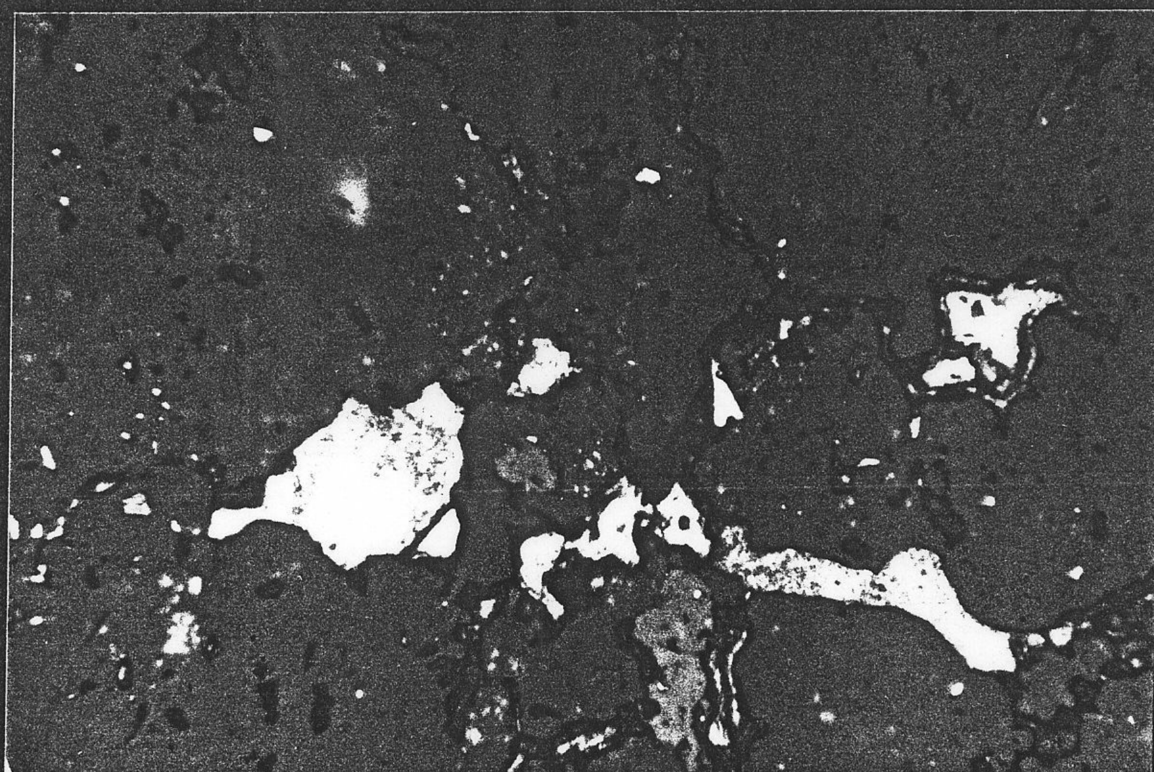
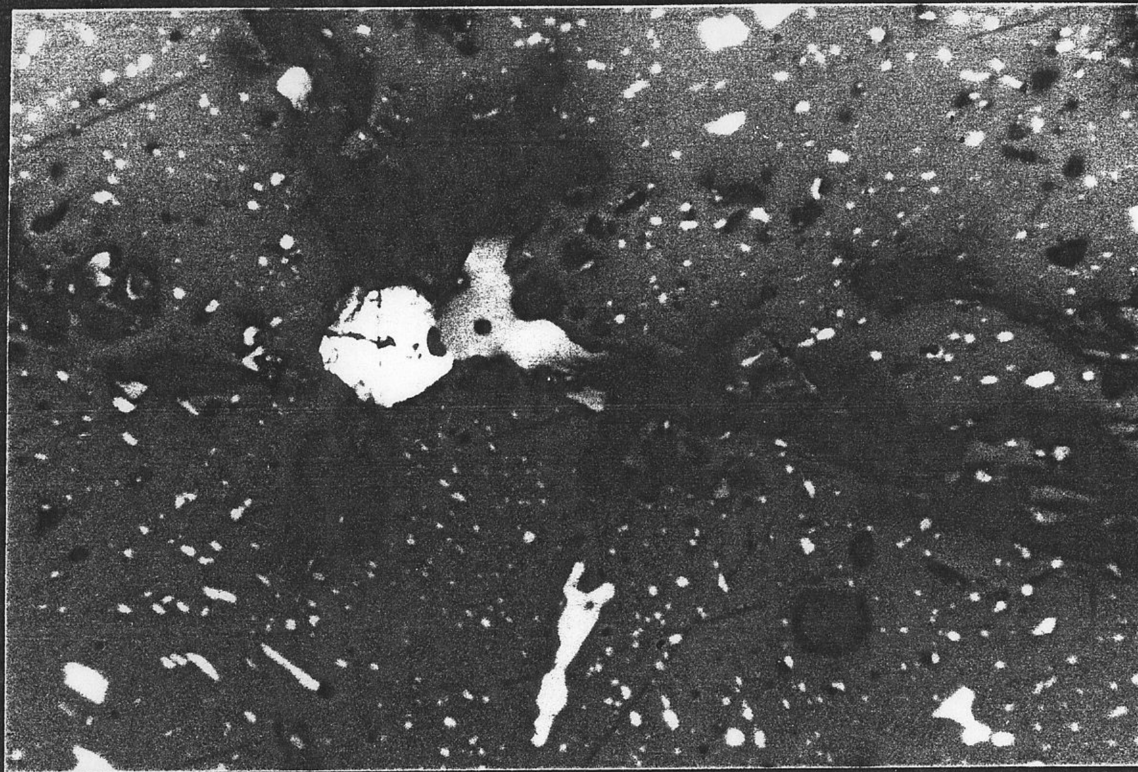


Plate 2 c: Electrum adjacent to pyrite, all contained in sphalerite grain from S-1 zone. Electrum grain is 3 μ in size. (400 X).

2 d: Free electrum and silver rich electrum with galena in sample DZ - 1a. Electrum grain on left is 100 μ long. (180 X).



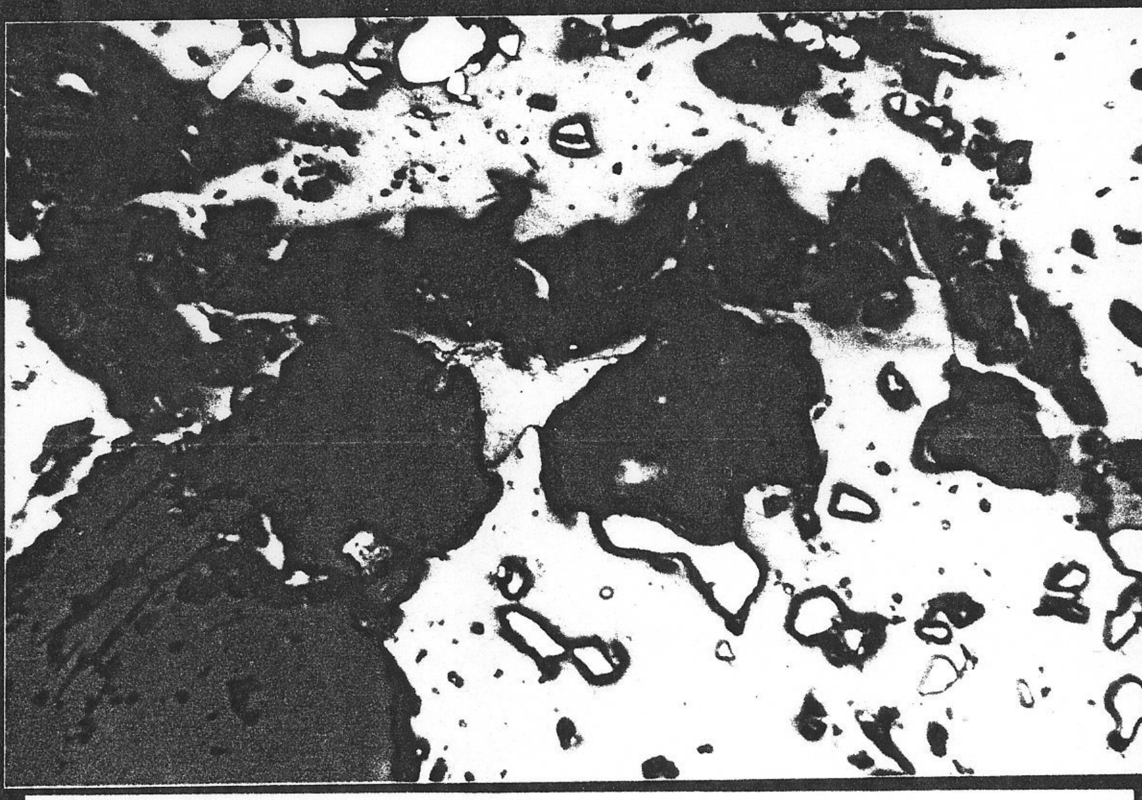
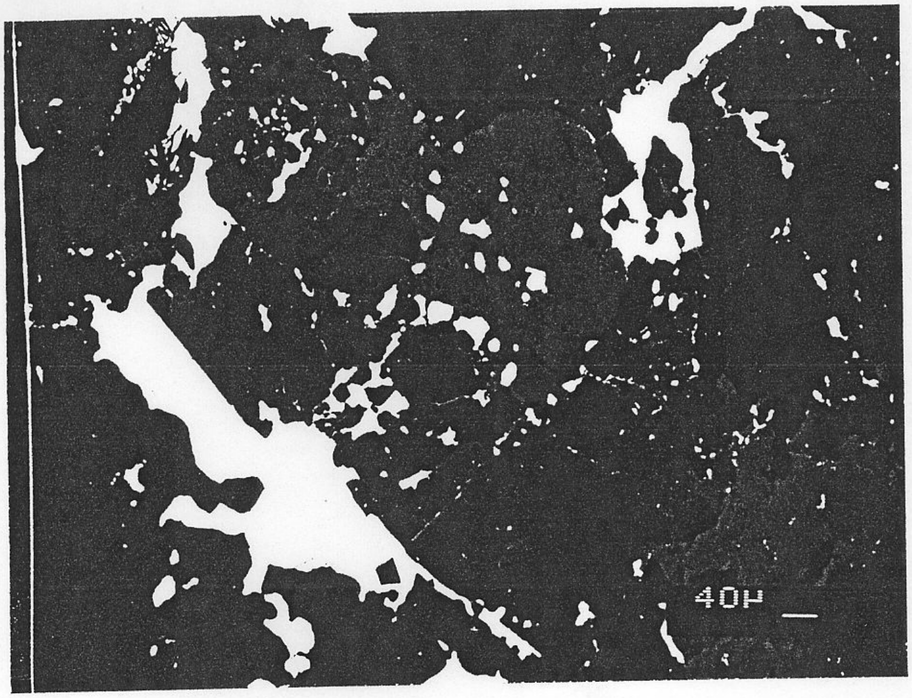


Plate 3 a: 30 μ electrum grain in sphalerite from SZ-1a. Composition is $Au_{60}Ag_{40}$. Note "exsolved" chalcopyrite.

3 b: Sphalerite associated electrum in DZ-1a. Silver rich margin is beginning to tarnish. (180 X).



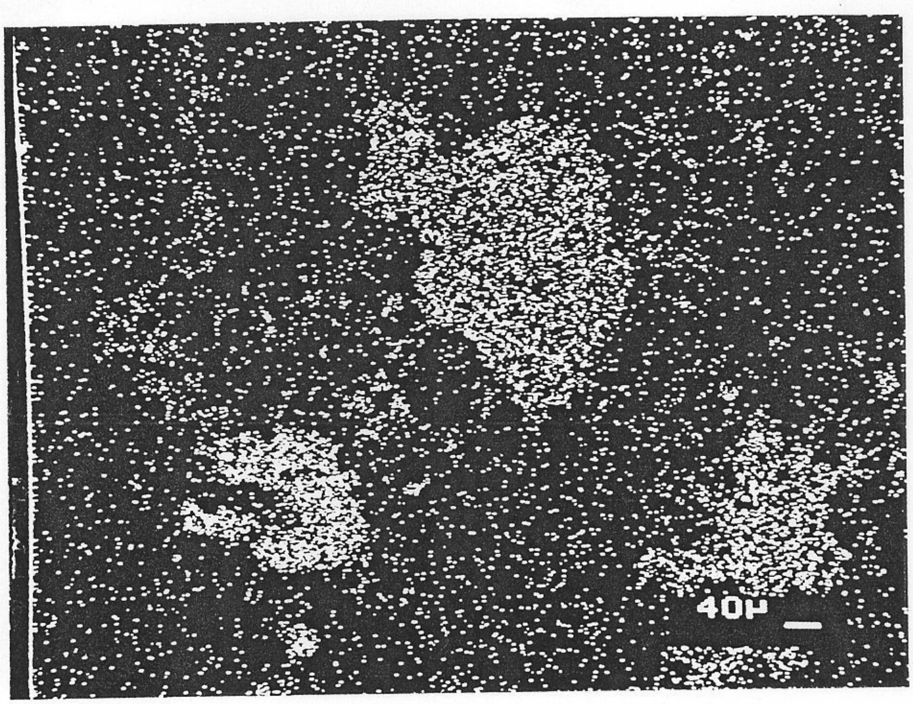


Plate 3 c: SEM backscattered electron image of pyrite (dark grey), sphalerite (medium grey), galena (white) and electrum (also white). Note the paragenetic relationships.

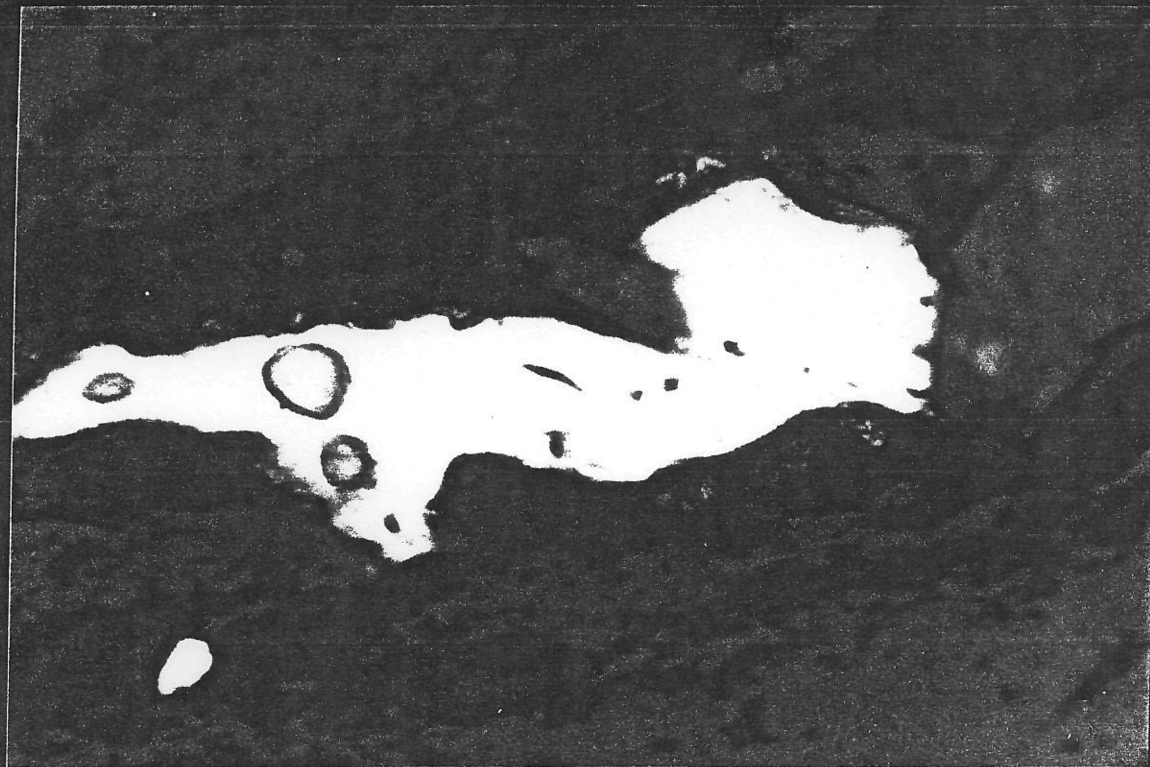
Plate 3 d: SEM element map. Density of dots corresponds to the amount of selected element present. Unfortunately high energy X-rays from zinc over-lap low energy X- rays from gold so that both electrum and sphalerite are shown.

and recoverable in jigs. It is possible that some gold may be lost in the pyrite concentrate.

3) As medium sized grains enclosed by quartz or carbonate gangue. This type of occurrence is most common in the sulphide poor samples of Dago zone. Generally,electrum occurs as rounded to elongated grains in quartz fracture fillings. A few grains were observed in crosscutting iron-carbonate veinlets. One electrum grain was observed enclosed by a slightly larger euhedral calcite grain which was set in a fine grained quartz matrix. Many of these grains will be free milling although the finer quartz-locked ones will require fine grinding (-270 mesh) for liberation.

<u>Native Silver</u>: is confined to samples from Dago zone. Unlike electrum, native silver commonly occurs as coarse grains enclosed by gangue in low sulphide rocks, although intergrowths with other sulphides do occur. Silver's major associations are chalcopyrite and argentite, with a weak affinity for galena. Even the free silver grains have small grains of chalcopyrite intergrown with or attached to them. Small inclusions of argentite within silver are common and an alteration relationship is possible. Some silver grains occur enclosed within pyrite, but the paragenetic relationship is not clear with only a two-dimensional view. Morphology of the native silver is irregular and the incorporation of gangue may lower the specific gravity enough to cause recovery problems.

<u>Argentite</u>: (really acanthite) is also restricted to the Dago zone. It most commonly occurs as anhedral grains intergrown with chalcopyrite and galena. Occasional grains are enclosed by pyrite but rarely is it associated with sphalerite. Within the Dago "hi-grade" samples (where it might be up to .5% by volume) it is complexly intergrown along fracture



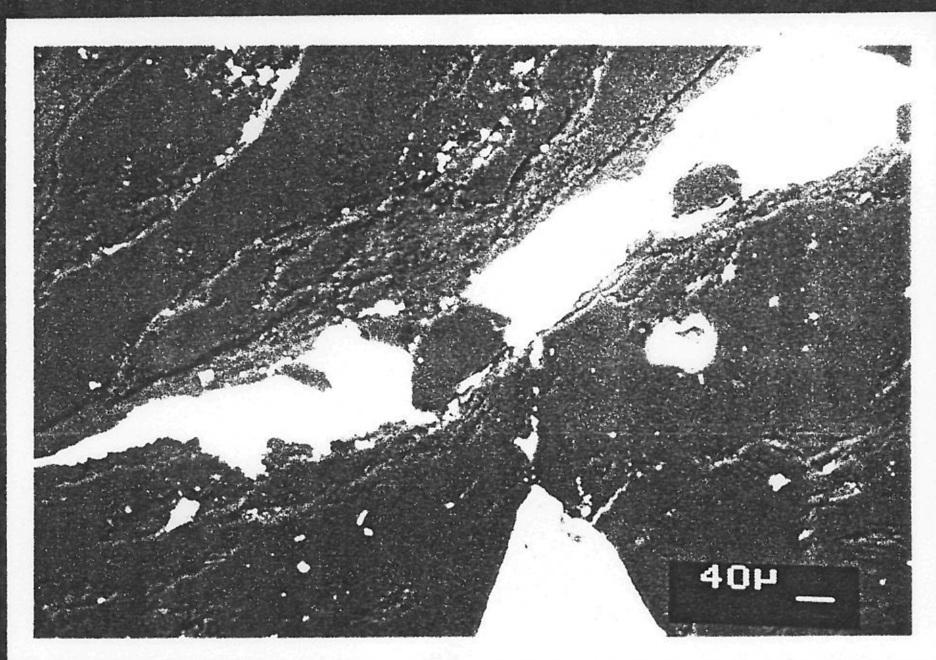
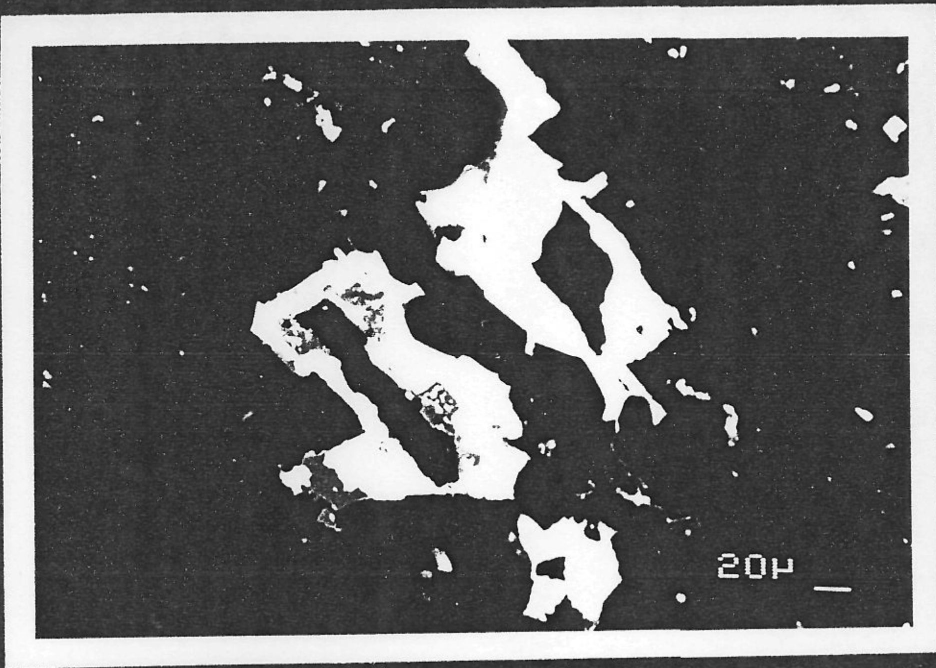


Plate 4 a: Native silver with included argentite (green) in Dago hi-grade sample.

4 b: SEM backscattered electron image of same as above with expanded field of view. Grey mineral rimming silver grain in center is chalcopyrite. Triangular grain in bottom center is pyrite. Scale on photo.



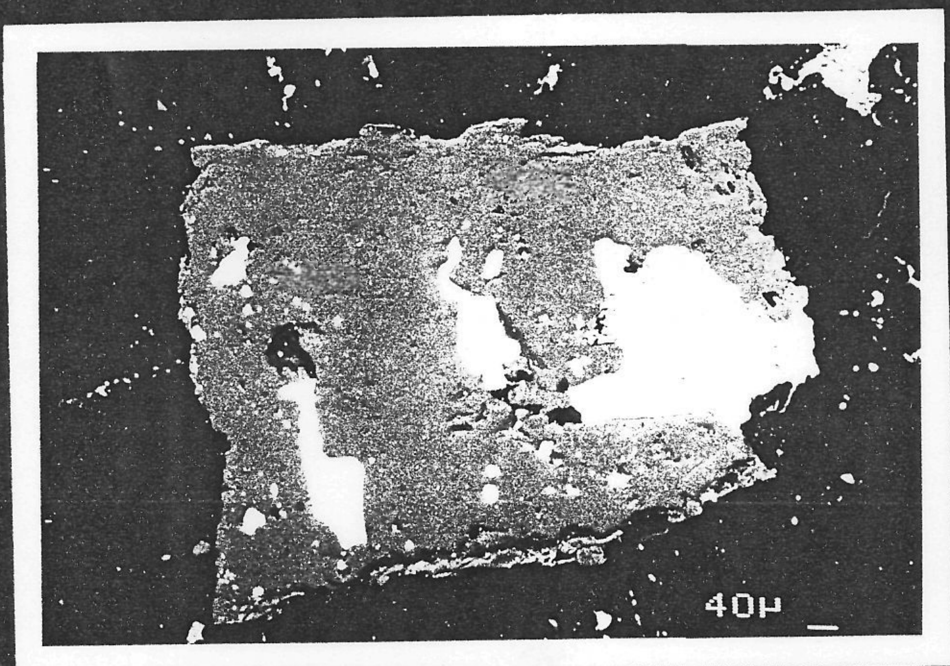


Plate 4 c: SEM BSE image of native silver from DZ - F_2. Dark grey intergrowth is chalcopyrite. Note the coarse grain size and irregular shapes.

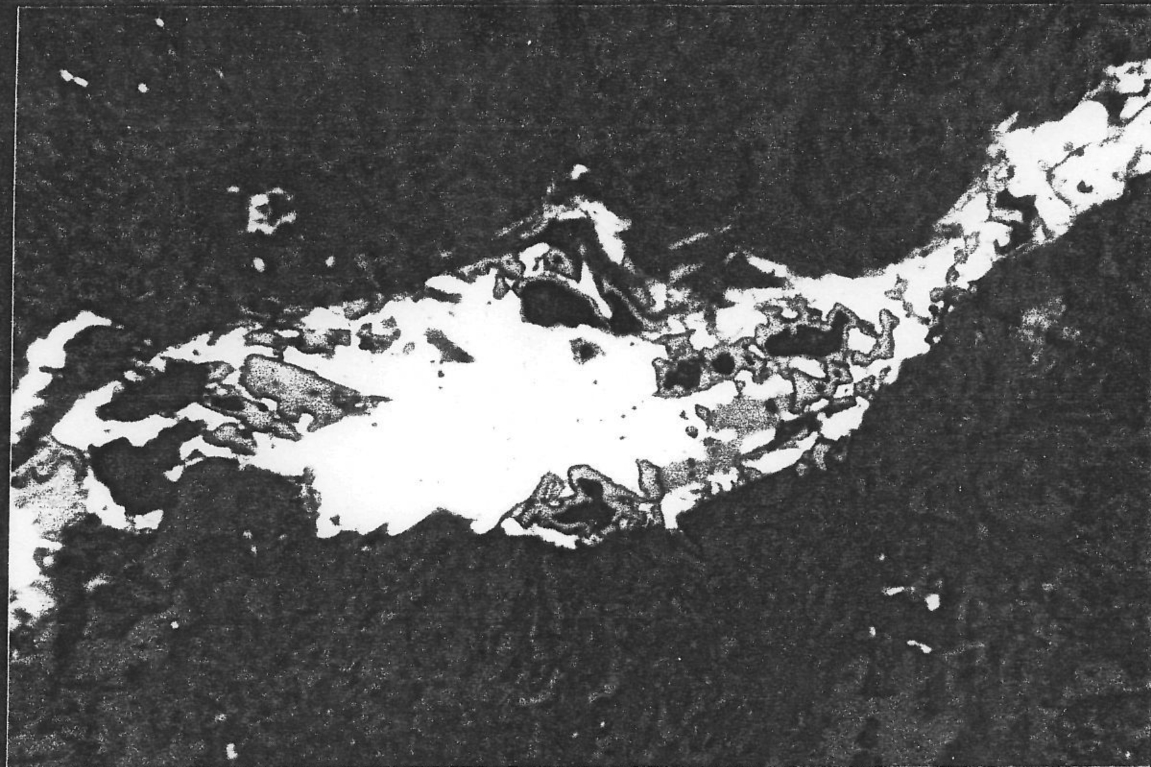
4 d: SEM BSE image of subhedral pyrite grain enclosing sphalerite (medium grey), native silver (light grey) and galena (white). From DZ - F1.

fillings with siderite, galena and chalcopyrite. Grains vary from fine to quite coarse.

Of interesting but dubious value is the observation of rapid growth of rosettes formed from euhedral acanthite blades (up to 10μ) on polished argentite samples (see photo).

Freibergite: is quite rare to the suite being observed in only two sections; one each from the Martha Ellen and Province zones. Its occurrence in the Dago zone is quite feasible and could be checked for by Sb analyses. In both the observed occurrences the silver content of the tetrahedrite was >10% and possibly near the maximum 18%. Trace quantities of iron and zinc were also detected within the tetrahedrite. Freibergite occurs as tiny grains encapsulated along with chalcopyrite, pyrite and manganiferous siderite in sphalerite grains in the Martha Ellen zone. Within the Province zone, freibergite forms "cauliflower" like overgrowths on pyrite and sphalerite grains.

Pyrrhotite: is a limited occurrence within a near massive sphalerite sample from the Martha Ellen zone. It occurs as intergrowths in "exsolution" chalcopyrite within sphalerite grains. The sphalerite host is not iron saturated. This occurrence might be attributed to a local thermal event (dyke emplacement) rather than chemical controls. Strain features within this section support this explanation.



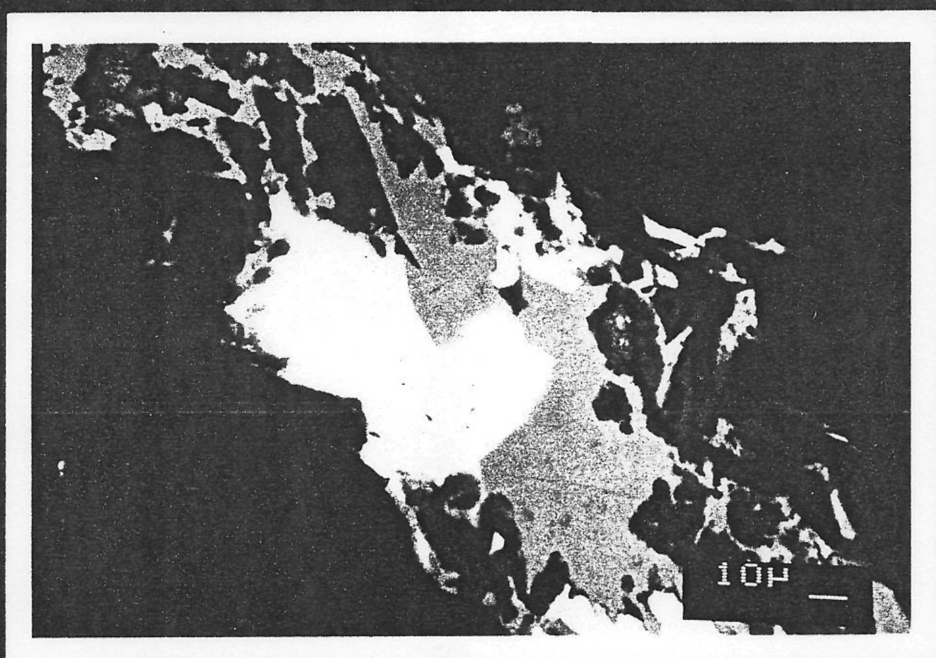
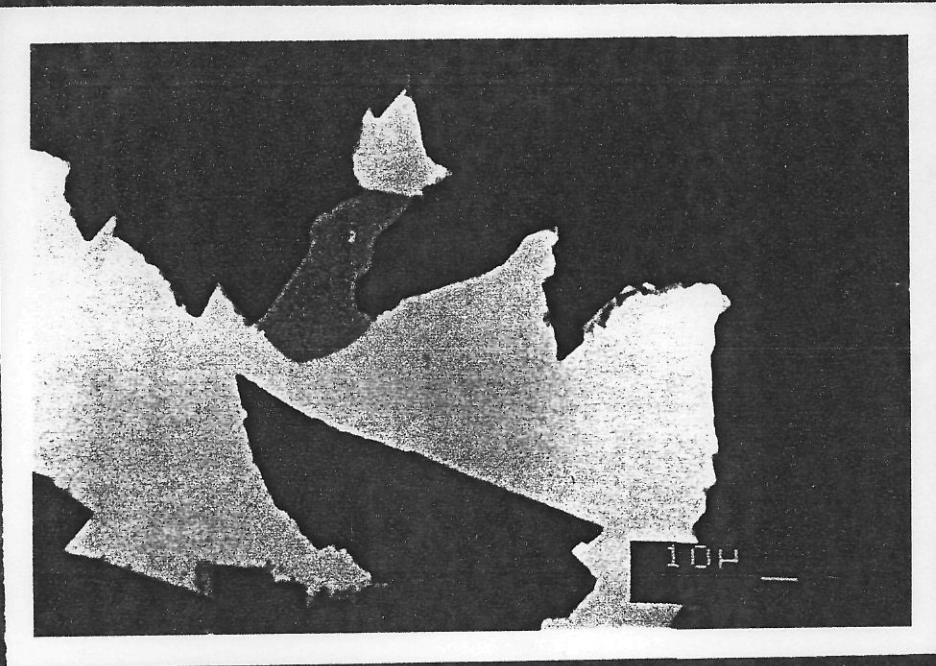


Plate 5 a: Intergrown galena (white), argentite (light green-grey), siderite (dark grey), and chalcopyrite (yellow) along a fracture in Dago hi-grade. Green mineral is tarnished (?) galena.

5 b: SEM BSE image of the above.



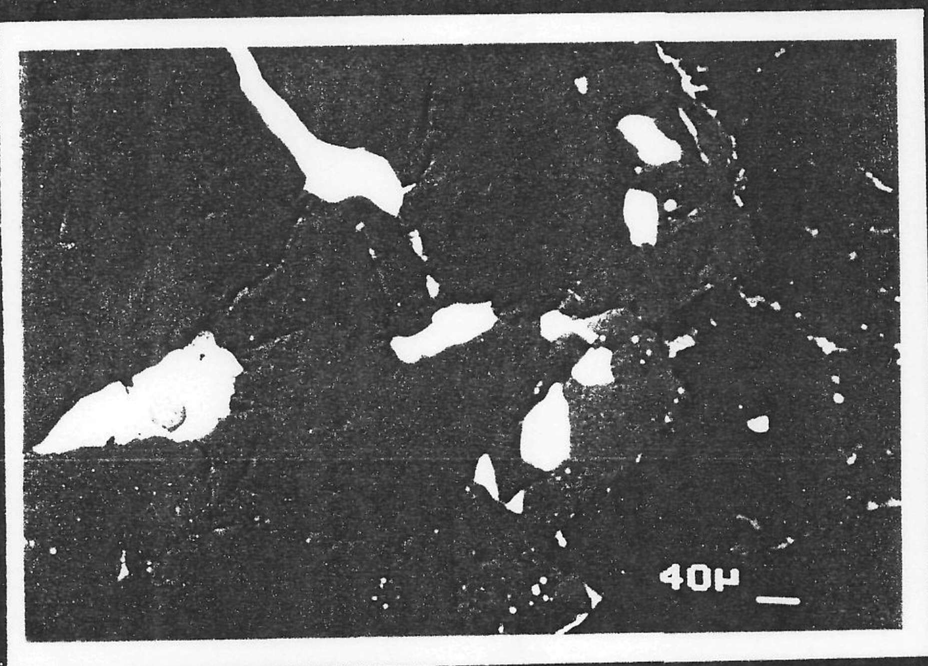
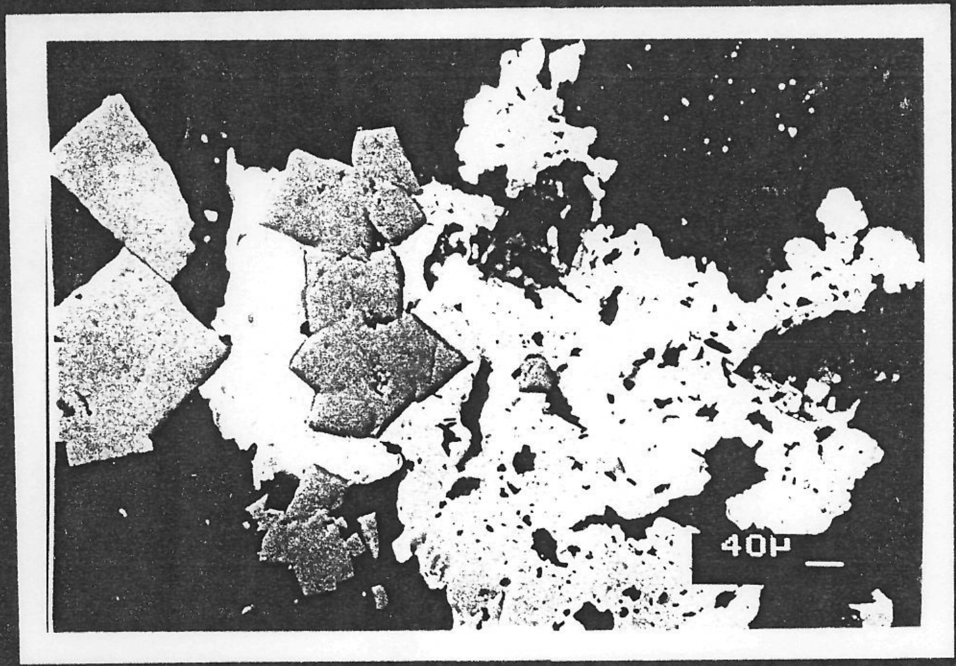


Plate 5 c: Argentite (grey) with galena (white) from DZ - F2. SEM - BSE.

5 d: Pyrite (dark grey) enclosing electrum (white) and argentite (light grey) in sample DZ - F2. Quartz gangue is black.



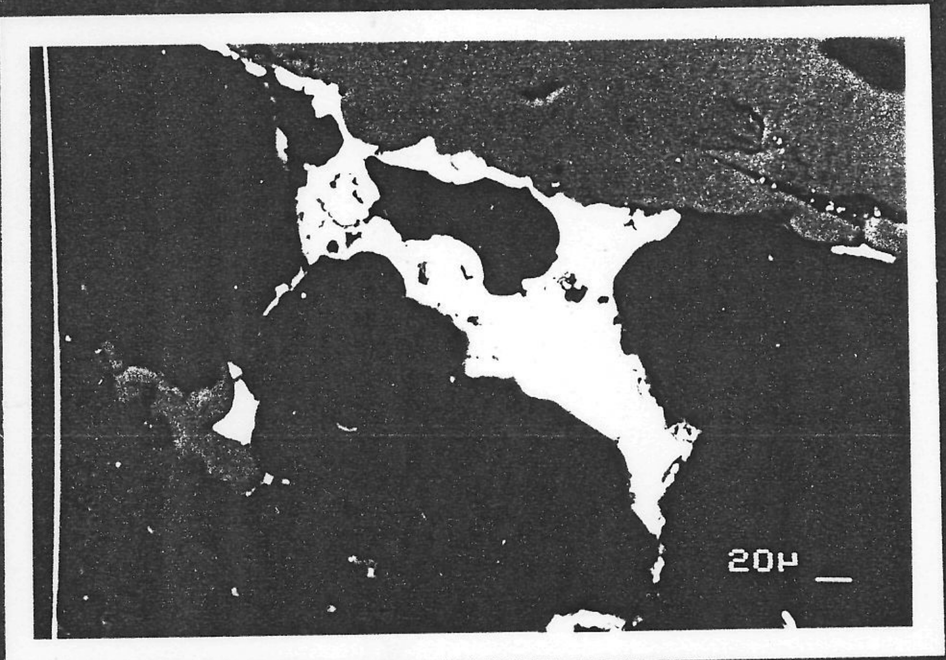
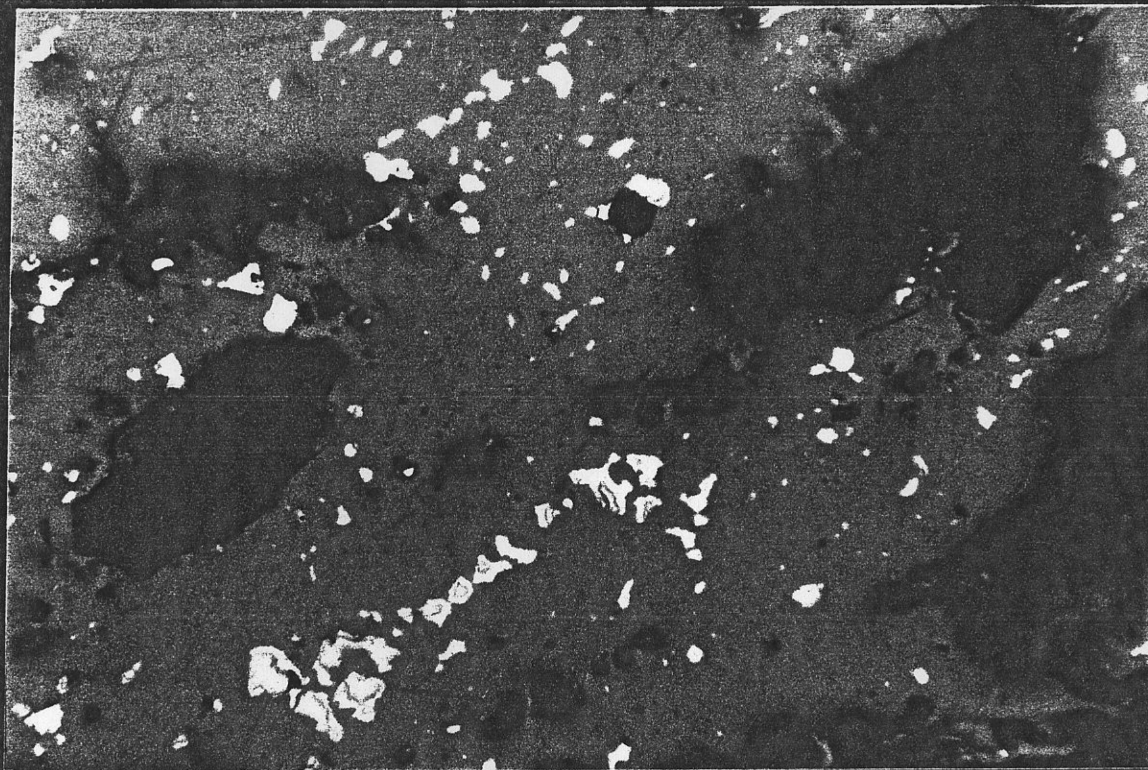


Plate 6 a: Cauliflower overgrowths of freibergite (light grey) on sphalerite (medium grey). White material is galena. Note euhedral pyrite (dark grey) and the amount of enclosed gangue within sphalerite. BSE image of PZ - 1b.

6 b: Anglesite (light grey) forming around galena (white) near large sphalerite grain in PZ - 2b.



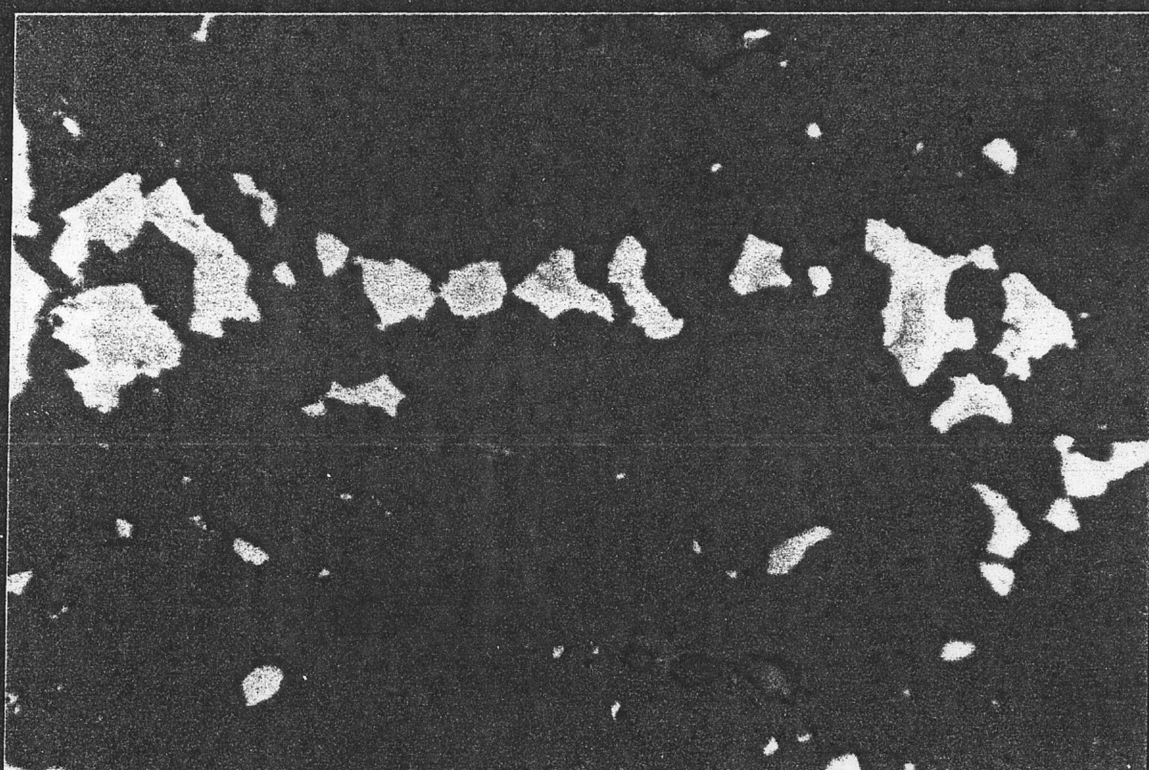


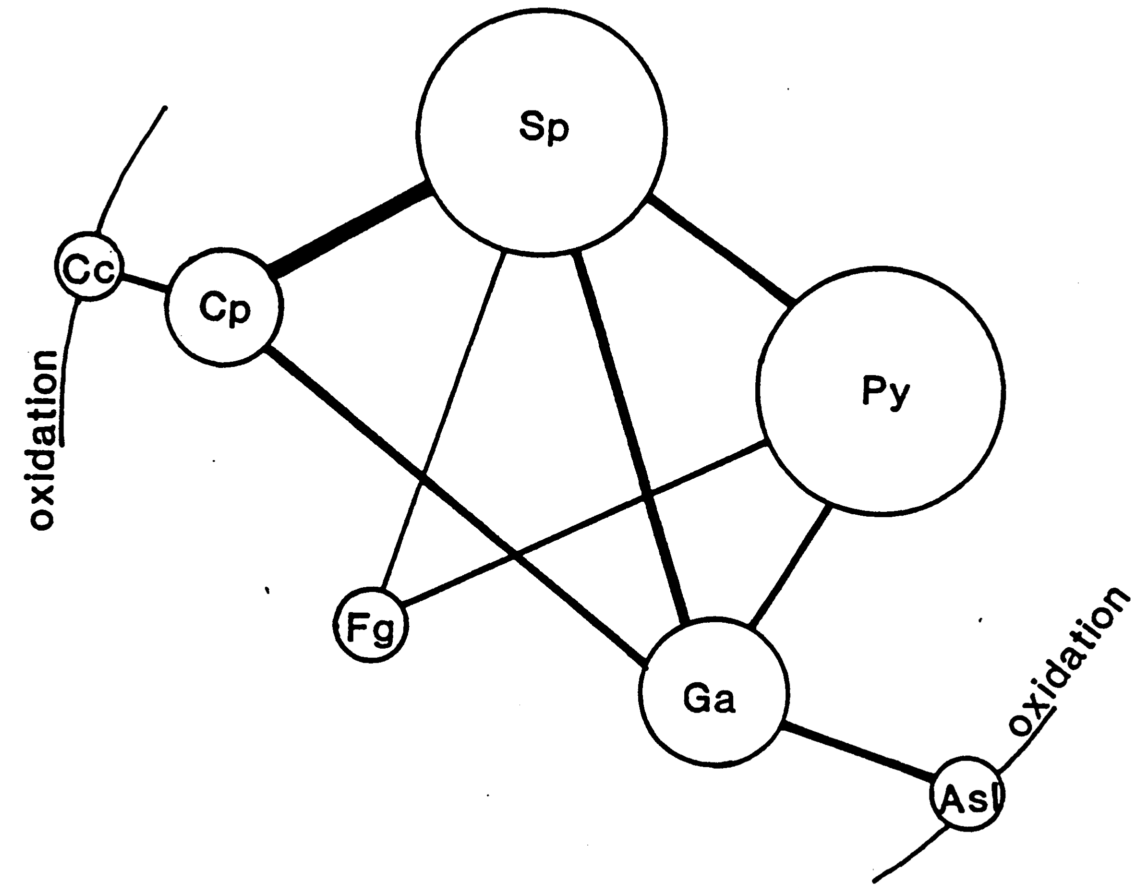
Plate 6 c,d: Pyrrhotite (pink) - chalcopyrite intergrowths in sphalerite from MEZ - 2. Top at 90 X, bottom at 270 X.

2.3 Paragenesis:

In a rough way, zones can be characterized by their mineralogical assemblages and abundances (see figures 1 - 3). For instance, the Dago zone contains samples with three distinctive assemblages: the D zone, similar to the S-1 zone, is characterized by high Au/Ag ratios and the occurrence of Cu-free sphalerite; the 3F sample, similar to the Province zone, is characterized by a oxidation assemblage and a higher lead content; and the F-zone, which is unique, is characterized by low Au/Ag ratios but high precious metal/base metal ratio. The Martha Ellen zone is texturally similar to the S_1 samples, but mineralogically more like the Province zone. The crystallization history or paragenetic sequence (figure 4) is similar for all the zones and appears to indicate a simple cooling process.

The first sulphide to crystallize was pyrite which had nearly finished crystallizing prior to other sulphide deposition. At least some pyrite crystallized after lithification as a few grains cut across fragment-matrix boundaries. A minor amount of pyrite crystallized after sphalerite, possibly indicating a weak second phase of mineralization. Pyrite was followed in the paragenetic sequence by sphalerite which grew around and occasionally partially replaced euhedral pyrite grains. During sphalerite crystallization copperrich fluids were engulfed or attached epitaxially and crystallized slightly later. Abundant intergrowths between sphalerite, galena and chalcopyrite testify to some co-precipitation of these phases. Later galena and chalcopyrite crystallization is indicated by rim or overgrowth textures. Post crystallization remobilization of galena and chalcopyrite is the best explanation for fracture fillings and interstitial fillings within broken pyrite grains. Electrum began to form during the last stages of sphalerite

Province Zone



Explanation

Asl - Anglesite

Arg - Argentite

Cp - Chalcopyrite

Cc - Chalcocite

E - Electrum

Fg - Freibergite

Ga - Galena

Ag - Native Silver

Py - Pyrite

Po - Pyrrhotite

Sd - Siderite

Sp - Sphalerite

Figure 1. Vander Veer type diagram showing sulphide phase relattionships within the Province zone. Size of the circle indicates the approximate relative abundance of the phase that it encloses. Thickness of the connecting lines indicates the strength or degree of association.

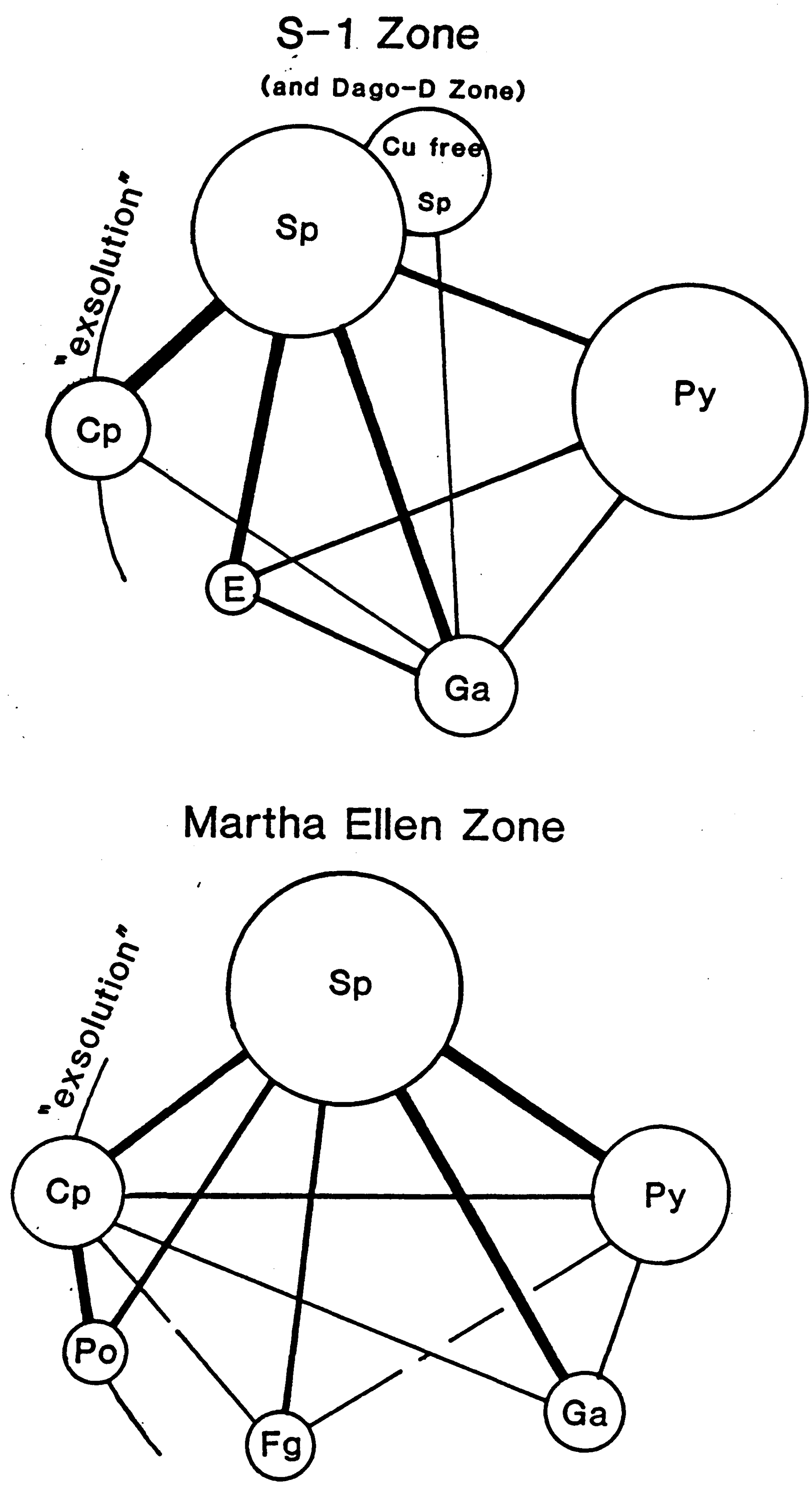
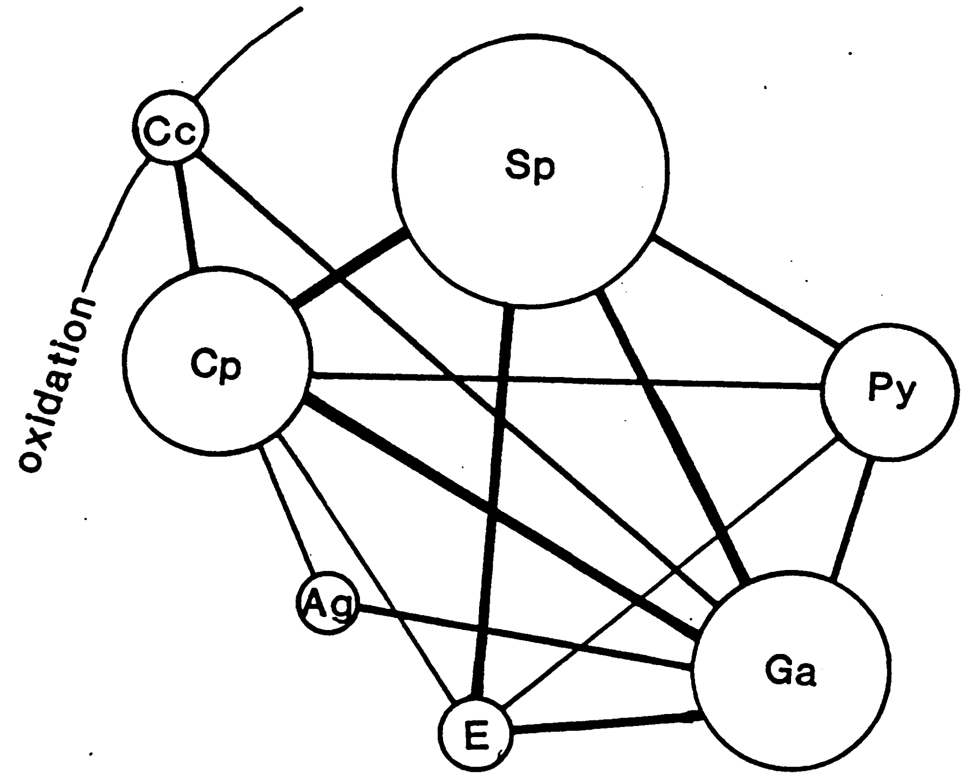


Figure 2. Vander Veer type diagrams for the S-1 and Martha Ellen zones. See figure 1 for explanation. The S-1 zone diagram is nearly identicle to the Dago D-zone diagram.

Dago 3F Samples



Dago-F Zone

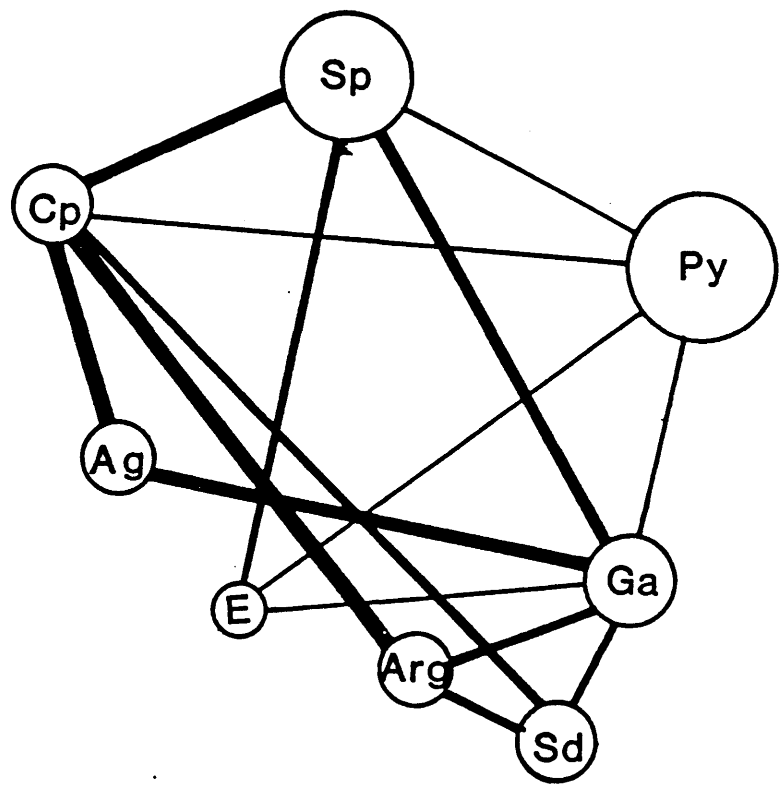
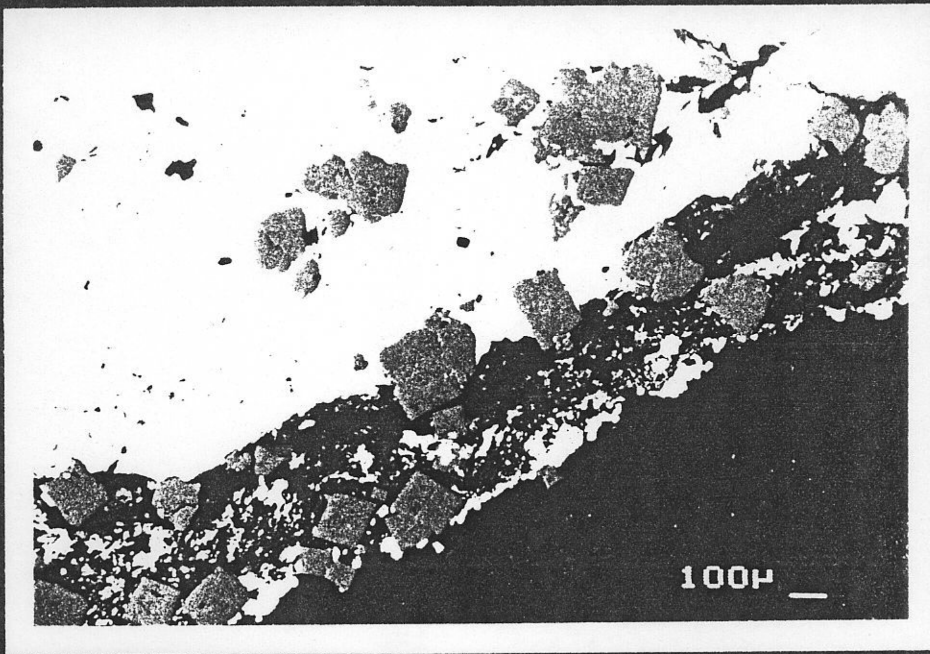


Figure 3. Vander Veer type diagrams for Dago 3F samples and F zone. The 3F samples were quite different from the other Dago samples - showing greater similarity to the Province zone.



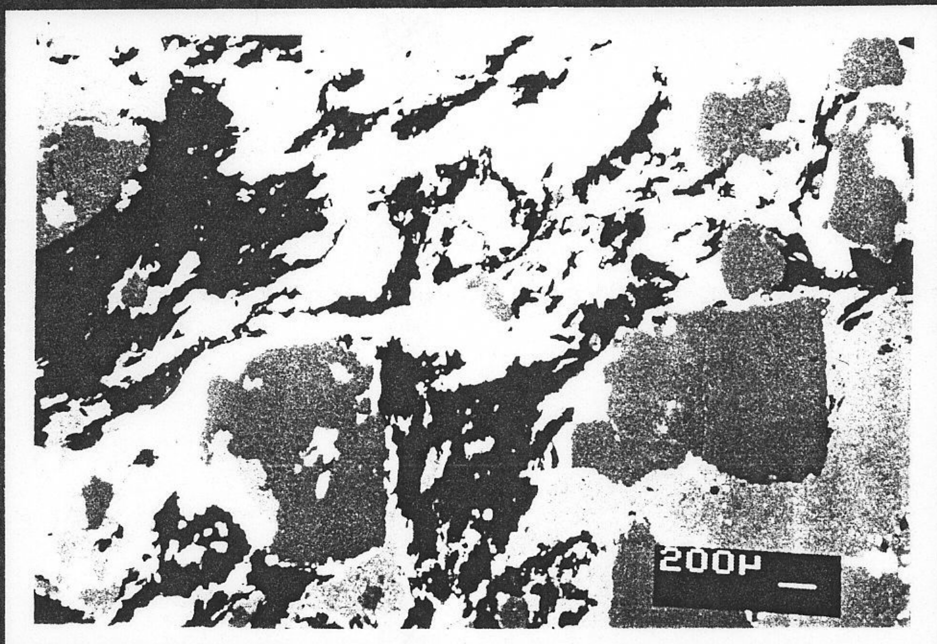
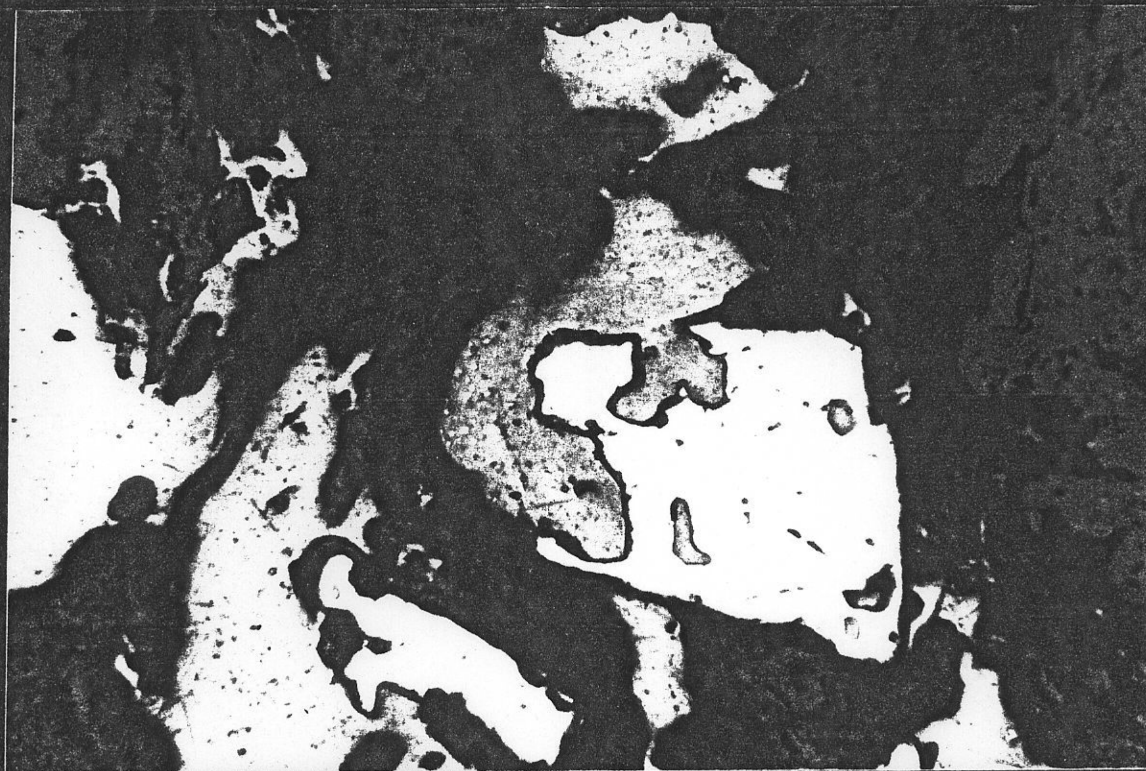


Plate 7a: Early euhedral pyrite grains enclosed by sphalerite with intergrown galena. Note the distinct banding. PZ-1b.

7b: Paragenetic sequence of pyrite-sphalerite-galena displayed by PZ-3c.



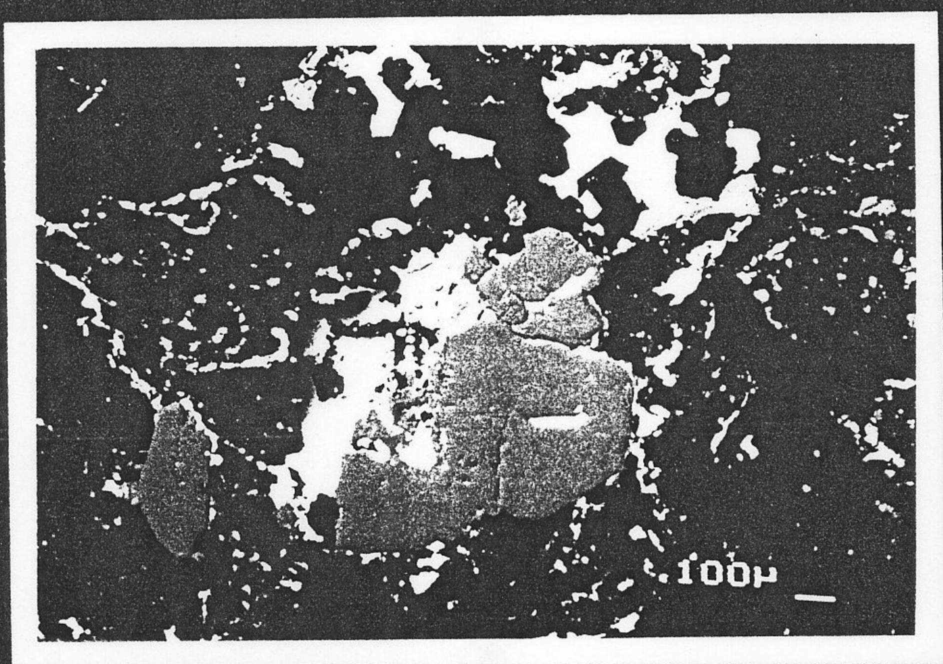


Plate 7c: Sphalerite (greenish grey) partially replacing pyrite (bright yellow). 90X.

7d: Argentite (light grey) growing around pyrite (dark grey) in DZ-2b.

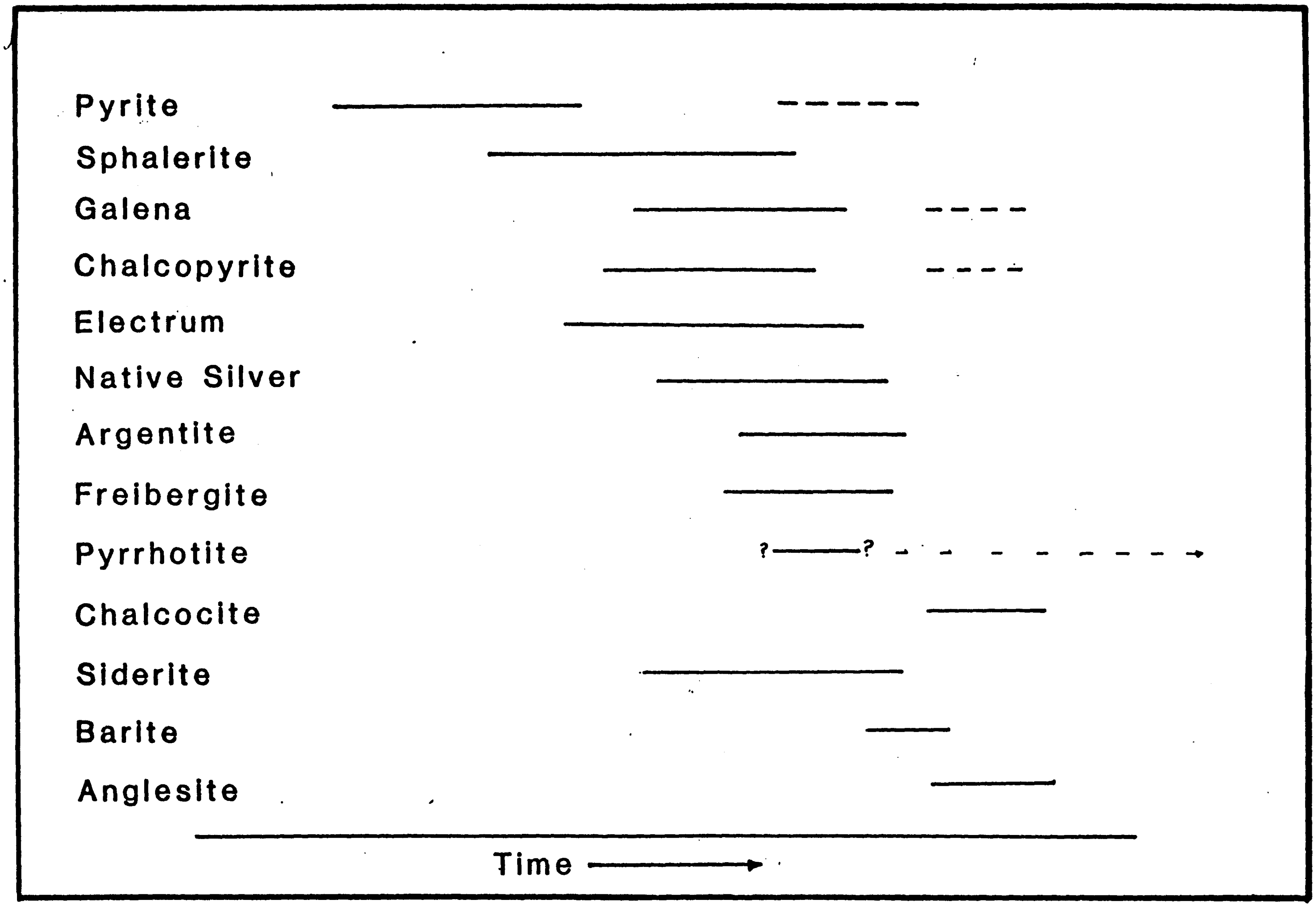


Figure 4. Paragenetic line diagram, composite from all sections.

formation and continued nearly to the end of the paragenetic sequence. The silver minerals began and finished their crystallization slightly after electrum, during the later part of chalcopyrite and galena formation. It is likely that there was more than a single stage of precious metal crystallization.

Carbonates were precipitating at various times all through the paragenesis as indicated by intergrowths with most sulphides.

Sometime after the mineralization event some of the zones were exposed to more oxidizing conditions and formed minor oxidation products.

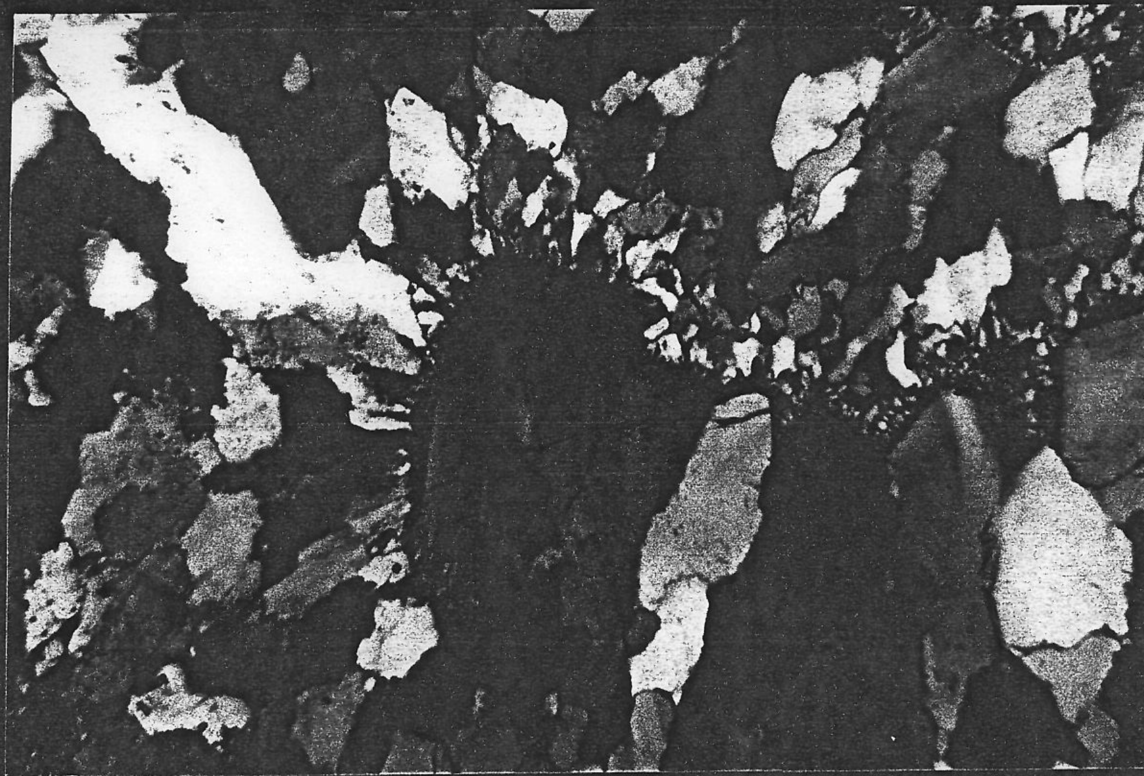
2.4 Petrology:

A polished thin section from a sulphide poor specimen in each zone was examined to determine gangue mineralogy and texture. Three of the sections, from white to grey siliceous rocks, displayed similar mineralogy and textures. Only the section from an altered fragment in a sulphide matrix breccia was different.

Sections from Province, S-1 and Dago zones consisted almost entirely of quartz with only minor carbonate, muscovite and opaques. Apart from the sulphides, the opaques occurred as a fine dusting within large quartz grains and along grain boundaries in finer material. Both optical and electronic means failed to identify the "dust" which likely consists of carbonoeous material. Quartz textures are variable and include combs of coarse, zoned and terminated crystals in a finely, interlocking crystaline matrix, and cockade structures of coarse quartz fragments surrounded by radiating fine crystaline aggregates. These textures indicate low pressure, open space fillings and are remarkably similar to textures observed in young epithermal silver deposits. All of the quartz is strained, showing undulose extinction.

Plate 8a: Cockade texture in quartz gangue from DZ-4. Fine grained quartz is outlined by black opaque material along margins.

8b: Zoned, pyramid terminated quartz crystals forming comb texture in DZ-4.



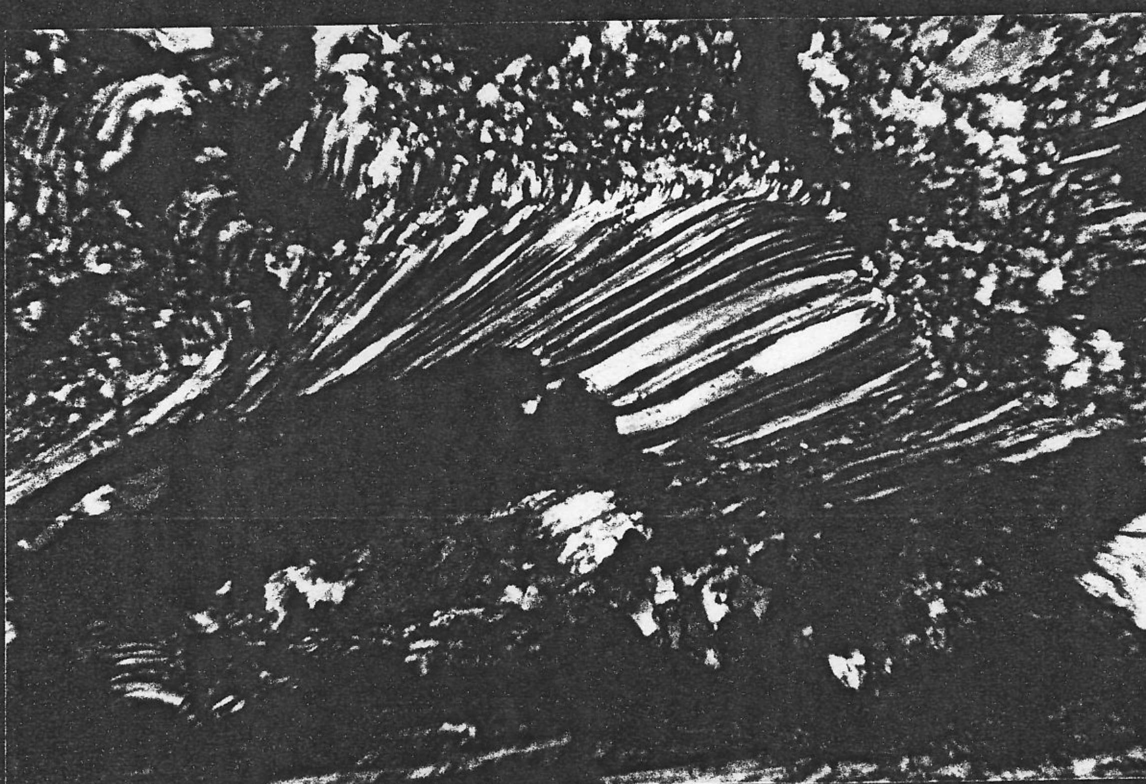


Plate 8c: Comb texture SZ-4.

8d: Growth structure in a mixture of quartz sericite and a K, (Fe, Mg) silicate (celdonite ?) adjacent to pyrite within a fracture. Note he metite selvage along lower edge of photo.

3 CONCLUSIONS

3.1 Benefaction.

Although precious metal occurrences are similar for most of mineralization types within the deposit enough differences exist that material from each zone or ore type should be included in metallurgical testing. For at least one of the zones it would appear that economic recovery of base metal is viable. During development work various ore types might be distinguishable by utilization of the following ratios: Au/Ag, Sb/Ag, Pb + Cu/Zn.

The proportion of free milling electrum will vary from zone to zone, but would be in the order of 75% for the entire deposit. Up to 10% of the electrum could finish up in the zinc concentrate with a similar amount contained by the other sulphides, particularly pyrite. A small amount of electrum contained within quartz would require very fine grinding and a cyanide type circuit for recovery.

Possibly less than half of the native silver will be recoverable in the jigs as intergrown gangue may drastically lower the specific gravity. Oxidation of silver, particularly in a seasonal operation, could present recovery problems. Argentite will likely follow chalcopyrite and/or galena through processing.

Sulphide intergrowths are either coarse and/or simple enough to allow separation during milling. Possible exceptions would include the fine gangue, chalcopyrite and galena trapped in sphalerite and the very fine argentite and electrum within pyrite.

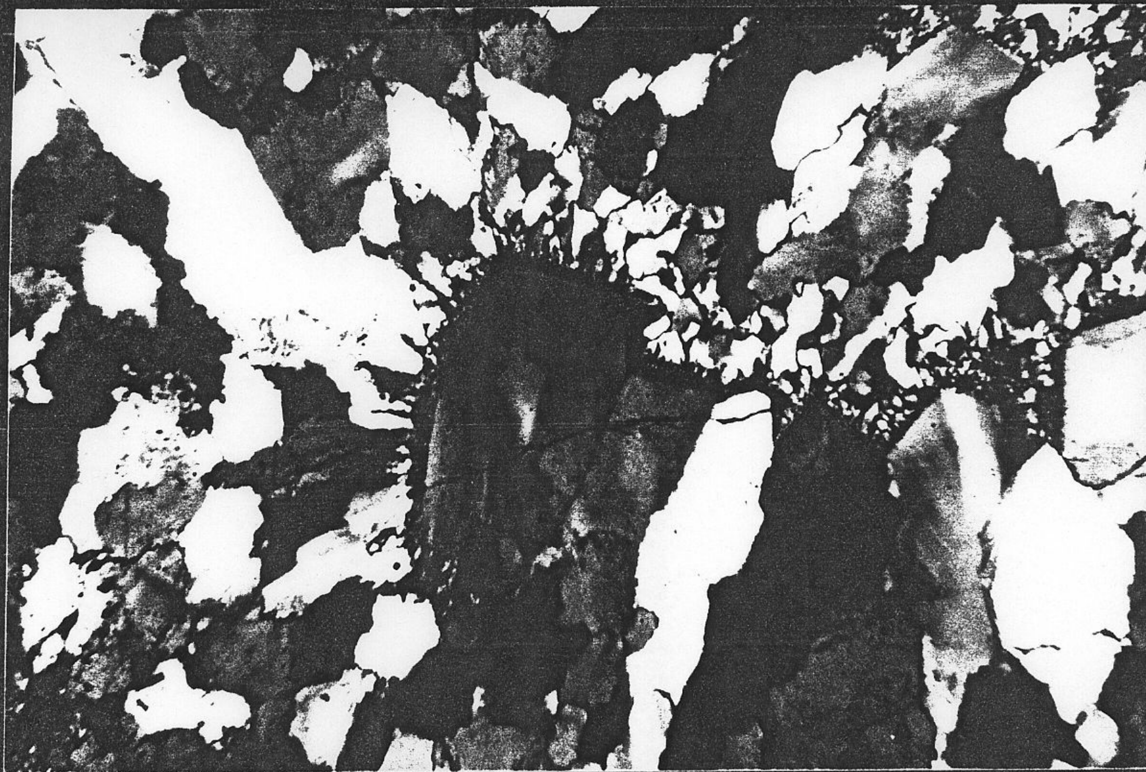


Plate 8c: Comb texture SZ-4.

8d: Growth structure in a mixture of quartz sericite and a K, (Fe, Mg) silicate (celdonite ?) adjacent to pyrite within a fracture. Note he metite selvage along lower edge of photo.

3.2 Ore Genesis

The origin of mineralization at the Big Missouri deposit will not determine its economic viability but it may influence exploration. The following section is based on the present study, a brief property tour and information from Galley (1981) and is, therefore, restricted by a limited data base.

Textures and morphology of Big Missouri mineralization indicate shallow and near surface to surface deposition. Stockwork breccias, which form most of the mineralization, can be interpreted as feeders for the massive or semi-massive mineralization (although present spatial relationships are uncertain). These features in addition to the island arc, andesite host rocks would naturally invite comparisons to the well studied Kuroko type deposits. A textural feature characteristic of Kuroko deposits which is not observed at Big Missouri is a clastic or fragmental texture within the sulphides due to initial precipitation in volcanic vents and subsequent brecciation and redeposition during phreatic eruptions (Clarke, 1983).

The most obvious difference between Big Missouri and Kuroko mineralization is that of composition or mineralogy. Kuroko mineralization is copper dominated and contains considerable volumes of sulphate minerals whereas Big Missouri is zinc dominated and contains only a trace of sulphates. If metals in the Big Missouri deposit were derived locally by seawater-geothermal leaching and deposited at the rock-ocean interface then a similar composition to Kuroko mineralization would be expected. The mineralogy of Big Missouri is very similar to that found at the Beaverdell and Silbak Premier deposits. Mineralogical and spatial similarities of Big Missouri and Silbak Premier strongly suggest a genetic relationship.

It is reasonable to suppose that the Big Missouri deposit is not volcanogenic (in the sense that mineralization was formed by volcanic activity) but rather is epithermal and synvolcanic (that is, high level, low temperature emplacement synchronous with, but not necessarily related to, volcanic activity). A somewhat analogous situation might be found at the Iron Dyke mine in Oregon (Juhas, et al, 1980). The implications of subtle but significant differences in ore genesis are:

- metal zonation relating to depth of deposition,
- less stratigraphic and paleo-topographic, and more structural, controls of mineralization.
- the possibility of another Silbak type deposit at depth (if Big Missouri is spatially unconnected to Premier).

3.3 Recommendations.

An estimate of the overall Au/Ag for the deposit would be in the order of 0.1. During Cominco's operation recoveries were in the order of Au/Ag = 1. This is likely due to limited recovery of argentite, freibergite and possibly native silver. In an open pit operation recovery of 1 oz/tonne Ag could be critical. It should be determined if the various mineralization types described in this report can be distinguished by metal ratios. If so, then these ore types should be metallurgically tested in proportion to their tonnage and grade.

The use of the SEM/EDS in ore miscroscopy and pre-metallurgy studies is rapidly becoming standard procedure. Its value to this study was limited to the identification of silver bearing phases, compositional analysis and the identification of submicroscopic electrum. For the most part mineralogy of the Big Missouri deposit was simple and coarse enough to be resolved by optical methods. Chemical and/or optical methods should be sufficient for further work. However, for fine grained and more complex ores the SEM/EDS is indispensable.

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PZ-1a

Rock Description: Specimen appears to be a breccia of some variety. The section is made up of a silicified andesite (?) fragment at least 3 cm long set in a quartz and sulphide matrix. Alternatively section could be part of a vein and related wall rock. Fragment is full of finely disseminated euhedral pyrite grains. A few discreet highly anhedral chalcopyrite grains occur within the fragment as well. Sulphides are generally much coarser grained in the matrix than within the fragment. Sphalerite is the dominant matrix sulphide.

Sphalerite: 13%. Dark to black in colour, sphalerite forms a near massive band up to 7mm wide across the section. Elsewhere it occurs as coarse aggregates. Approximately 15% of the sphalerite volume is made up of intergrown or "exsolved" chalcopyrite and galena. Quite a bit of gangue and pyrite was entrapped during sphalerite crystallization.

Pyrite: 13%. Occurs as finely disseminated euhedral grains within the fragment and as semi- massive aggregates of fine euhedral to subhedral grains within the matrix. Interstitial chalcopyrite within the aggregates is common. Some of the larger pyrite grains are distinctly corroded.

Chalcopyrite: 5%. Intergrowths within sphalerite are strongly associated with galena. Discreet grains are relatively coarse and occur peripheral to sphalerite. Chalcopyrite also occurs interstitially to pyrite grain aggregates.

Galena: 4%. Occurs as fine to medium sized lenticular blebs within sphalerite. Also found as rims and fracture fillings around and within other sulphides.

Paragenesis:

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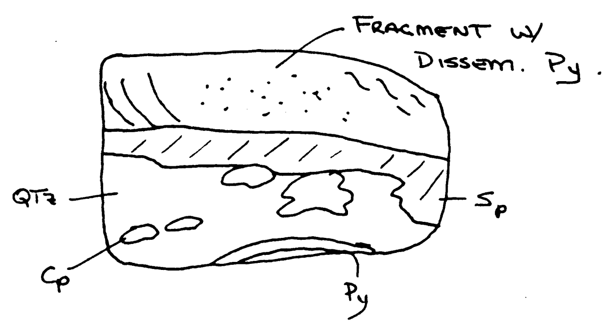
        Py -----  -
        Sp   ----------
        Cp      ---------
        Ga        ---------
       ________________________
              time
```



PZ-1b

Rock Description: Sample appears to be all quartz or silicified material and sulphides. The morphology of the section suggests that it may be a vein as it composed of subtly banded sulphide layers divided by a quartz band.

Sphalerite: 20%. Generally as very coarse aggregates of assorted shaped crystals, some containing up to 5% "exsolved" and/or intergrown chalcopyrite. Much gangue was entrapped during crystallization. Galena is quite abundant as intergrowths. The characteristic sphalerite shape for this section is an elongate bleb with wavey edges, usually about 1mm long.

Pyrite; 8%. Occurs as euhedral to subbedral crystals and crystal aggregates. Most is quite intimately associated with sphalerite, but some, usually smaller grains, appear to be paragenetically later.

Galena: 3-4%. Commonly occurs as amoeboid intergrowths within sphalerite or as subhedral blebs. Often associated with chalcopyrite, particularly when within sphalerite. There is some late stage crystallization or remobilization of galena as it forms thin rims on other sulphides and long thin fracture fillings.

Chalcopyrite: 2%. Almost all occurs as "exsolution" blebs or intergrowths within sphalerite and/or galena. A small amount occurs as thin rims on, or interstitially to, pyrite.

Freibergite: trace. Only a few occurrences observed; all were as 'cauliflower' overgrowths on pyrite or sphalerite (or any other sulphide that was conveinent).

Paragenesis:

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Py   ------  -   -   --------
Sp        ----------
Ga              --------------
Cp              --------------
Fg                          --------
     ________________________________
               time --
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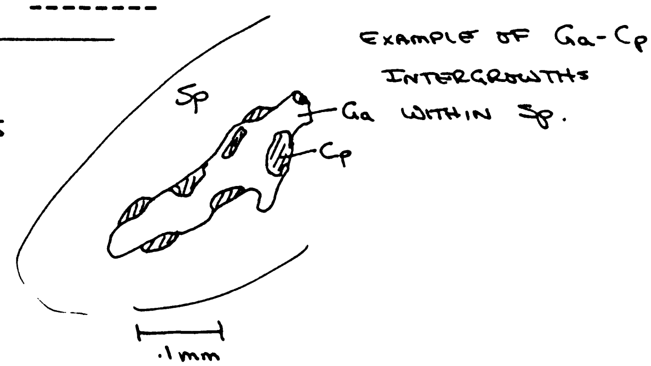

Notes: - tetrahedrite contains 10% Ag therefore termed freibergite.
- quartz band contains finely disseminated pyrite but few other sulphides.

PZ-2a

Rock Description: A siliceous section with coarse black sphalerite and medium sized grains and trains of pyrite in elongate semi-massive aggregates. Small bits of galena are visible to the eye but no chalcopyrite can be seen. However, under the low power objective a substantial amount of small iregular free grains of chalcopyrite can be seen. Within the sulphide poor sections of the matrix quite a bit of black material is observed. This material is hard, altough this may be due to silicification, and occurs along fractures resembling styolites suggesting that it is carbon.

Pyrite: 11%. Occurs as medium to fine, euhedral to anhedral, often crushed or broken, grains and grain aggregates. Grains and grain aggregates are frequently surrounded or enclosed by sphalerite, but the reverse relationship occurs often enough to cast doubt upon the inferred paragenetic sequence.

Sphalerite: 7%. Occurs as coarse subhedral to anhedral grains with "exsolved" and/or intergrown and/or encapsulated chalcopyrite (5%), galena (2%), pyrite (4%), and gangue (up to 10%). A few grains are 50% intergrowths with galena. Mineralization appears to have begun along fractures but is no longer confined to them.

Chalcopyrite: 2%. A much greater than average occurrence of free, variably shaped grains as well as abundant "exsolved" and intergrown blebs in sphalerite (up to 9% in some cases.) Paragenetically, chalcopyrite has a much greater association with galena and sphalerite than it does with pyrite.

Galena: 1%. Comes in the standard occurrence: fine to very fine disseminated grains in sphalerite and the matrix. Also as larger grains or rims around other sulphide grains. Quite strongly associated with chalcopyrite, both spatially and paragenetically.

Paragenesis:

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        Py  -----        --?--?--
        Sp      ----------
        Cp        -------
        Ga            ----------
        ________________________________
                 time --
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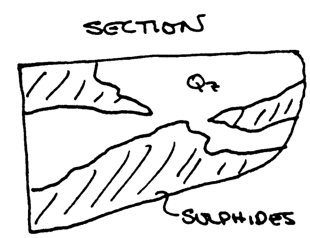
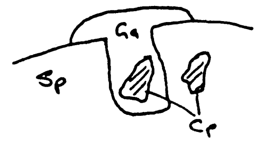
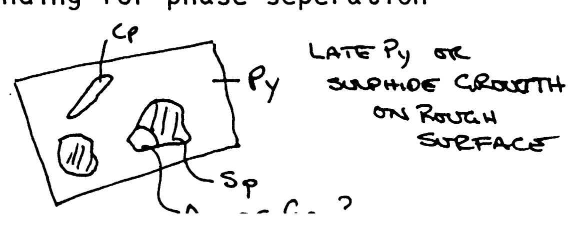




Notes: The most distinctive things about this section are the black stylolite fractures and the high degree of sulphide intergrowths which would reguire very fine grinding for phase seperation during ore dressing.



PZ-3a

Rock Description: Appears to be an altered fragmental andesite with about 40% sulphides. Sulphides, mostly pyrite and sphalerite, are somewhat interconnected massive to semi-massive aggregates. Shape of the sulphide aggregates gives the rock a slightly foliated appearrence, but this feature is not particularly well developed microscopically.

Pyrite: 14%. Occurs as medium sized euhedral to fine subhedral disseminations and aggregates. Some fine to very fine irregular and highly corroded and replaced grains. Pyrite is clearly early in the crystallization history.

Sphalerite: 11%. Grains vary from very fine disseminated wisps to highly irregular, deeply invaginated blobs of variable size. From 2 to 5% "exsolved" chalcopyrite is common, in some grains the "exsolution blebs have coalesced to form relatively coarse inclusions. Sphalerite is frequently intergrown with siderite.

Galena: 5%. Commonly as fine intergrowths with sphalerite and chalcopyrite. Also as remobilized grain coatings and fracture fillings. There are a few fine to coarse irregular blebs dispersed throughout the section, some of which are quite wispy.

Chalcopyrite: 2%. Occurs mostly within sphalerite but fine to medium, amoeboid to lenticular, free grains are not uncommon. Some grains appear to be remobilized along fractures.

Paragenesis: same as 3b.

PZ-3b

Rock Description: Section is semi-massive sulphide (sulphides 50%) with distinct banding and foliation perpendicular to core 'axis'. Bands are defined by sulphide type, carbonates, fragments, and silica.

Over the entire section sulphides are fine grained but some bands consist of relatively coarse pyrite or sphalerite.

Sphalerite: 17%. Possibly best described as 'clumps', sphalerite occurs as partially welded clusters of lenticular to irregular shapes. Approximately 4% "exsolved" chalcopyrite by volume. Abundant included gangue and intergrown galena.

Pyrite: 15%. Occurs as euhedral to subhedral grains both individually and as aggregates. Some bands contain quite coarse grains while other bands (carbonate or fragments(?)) contain relatively fine grains. Some grains are corroded. Most of the pyrite appears to have crystallized early and is often partially replaced by sphalerite.

Galena: 9%. Occurs in the standard fashion of dispersed blebs intergrown with chalcopyrite in sphalerite, but also strung out along fractures and grain boundaries. Also a few fairly coarse, discreet clots.

Paragenesis:

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Py  -------
Sp       ----------
Ga            ------------
Cp                ---------
_______________________________
            time --
```

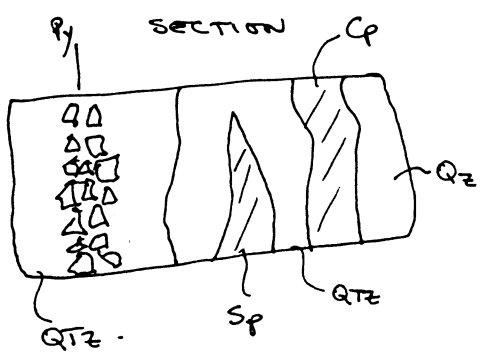

NB. BANDED TEXTURE.

PZ-3c

Rock Description: Section is made up of 50% coarse to finely intergrown sulphides. Intergrowths are complex and all permutations of paragenetic sequences can be found. Gangue appears to be a dark silicified andesite with clusters of massive and semi-massive sulphide.

Sphalerite: 20%. Occurs as large elongate grains with up to 10% "exsolved" and intergrown chalcopyrite. Frequently encapsulating gangue, Fe-carbonate, and other sulphides. Sphalerite grains are often rimmed by galena and/or chalcopyrite.

Pyrite: 9%. Occurs as corroded medium to coarse euhedral to subhedral grains. Most of the pyrite is paragenetically early, but some crystals enclose sphalerite or galena. Somewhat distinctive of this section is "exsolution" or entrapment of tiny chalcopyrite 'eggs' within pyrite. Pyrite has not participated in the complex intergrowth sequences of the other sulphides.

Chalcopyrite: 6%. Most is contained within the sphalerite but frequent free grains of various sizes and standard amoeboid shapes.

Galena: 4%. Occurs as intergrowths with sphalerite and chalcopyrite and as thin rims on any sulphide phase. Free grains are either of highly irregular shapes or as thin sinuous hairline fracture fillings.

Chalcocite: trace(?). Within a few of the chalcopyrite grains were thin green lines and blebs. EDS analyses of these yielded very high copper peaks with subordinate sulpher and iron peaks. Since chalcocite is white, it could easily appear green due to the edge effects of chalcopyrite (covellite is distinctly blue) and likely formed by oxidation of chalcopyrite.

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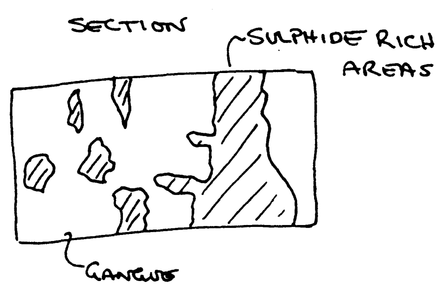
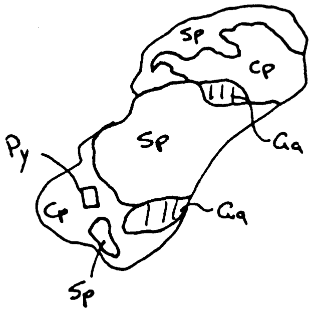
Paragenesis:
        Sp                ----------
        Py     ---- -        ---
        Cp                   -----------
        Ga                     -------------
        Cc                                   ---
       ________________________________
                   time --
```





EXAMPLE OF
Sp - Ga - Cp - Py
INTERGROWTH

Notes: -iron content of sphalerite is 2%.
-galena contains a trace of Gallium and one grain yielded small bismuth peaks.

SZ-1a

Rock Description: section is siliceous with densely packed subhedral pyrite grains and a sphalerite rich zone cutting through the center. Sphalerite is black.

Pyrite: 24%. Occurs as euhedral to subhedral grains in fine to coarse aggregates. Some aggregates become dense enough to be semi-massive. Very fine, often crushed, pyrite grains are dispersed throughout the section. Grain size is binodal from 20 to 0.2 mm.

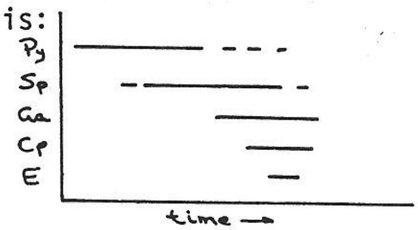
Sphalerite: 10%. Coarse to fine ameoboid grains and grain aggregates. Frequently crystallized around pyrite grains. Included and "exsolved" chalcopyrite can form up to 12% of the grain. Sphalerite also encapsulates abundant gangue and minor galena.

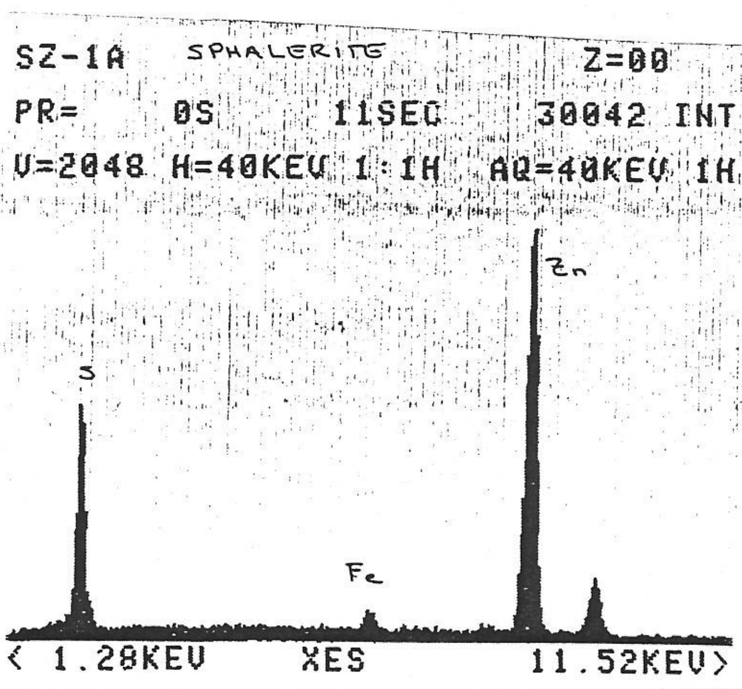
Chalcopyrite: 3%. Occurs mostly as inclusions or intergrowth within sphalerite. Some discreet, coarse, irregular grains and numerous tiny disseminated blebs. Very fine chalcopyrite fills fractures and irregularities in pyrite.

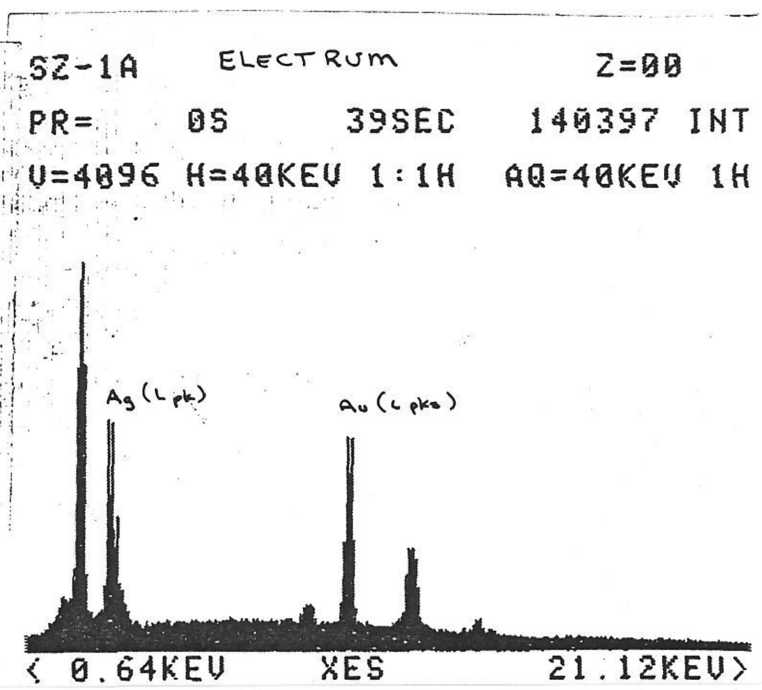
Galena: 1%. Confined mostly to inclusions in sphalerite with the remainder as intergrowths with chalcopyrite.

Electrum: trace. Occurs as medium to coarse grains along fractures or within sphalerite.

Paragenesis:







SZ-2a

Rock Description: A siliceous looking rock of semi-massive sulphides. Section has the appearance of a breccia, with an irregular shaped sulphide dominent area set in a sulphide poor matrix. Overall sulphide content is about 50% of which most is pyrite.

Pyrite: 30%. Occurs as fine to coarse euhedral to anhedral crystals and crystal aggregates. Commonly complexly intergrown with other sulphides and in some areas appears to have crystalized after sphalerite, forming a rim of small cubes surrounding an eliptical sphalerite grain.

Sphalerite: 9%. Forms large anhedral to irregular grains and aggregates. Entrapped gangue and galena is common but very little entrapped pyrite. Up to 4% of sphalerite is "exsolved" and/or intergrown chalcopyrite.

Galena: 3%. Appears to be late in the paragenetic seguence and occurs as irregular shaped blebs and grains, frequently with one or two sharp linear edges where crystalization terminated against carbonate grain boundarys. Galena is often interstitial to pyrite and chalcopyrite grain aggregates and intergrown wtih sphalerite.

Chalcopyrite: 2%. A few free grains in characteristic highly irregular shapes (one in particular is quite large - 4mm-), but most is tied up within sphalerite.

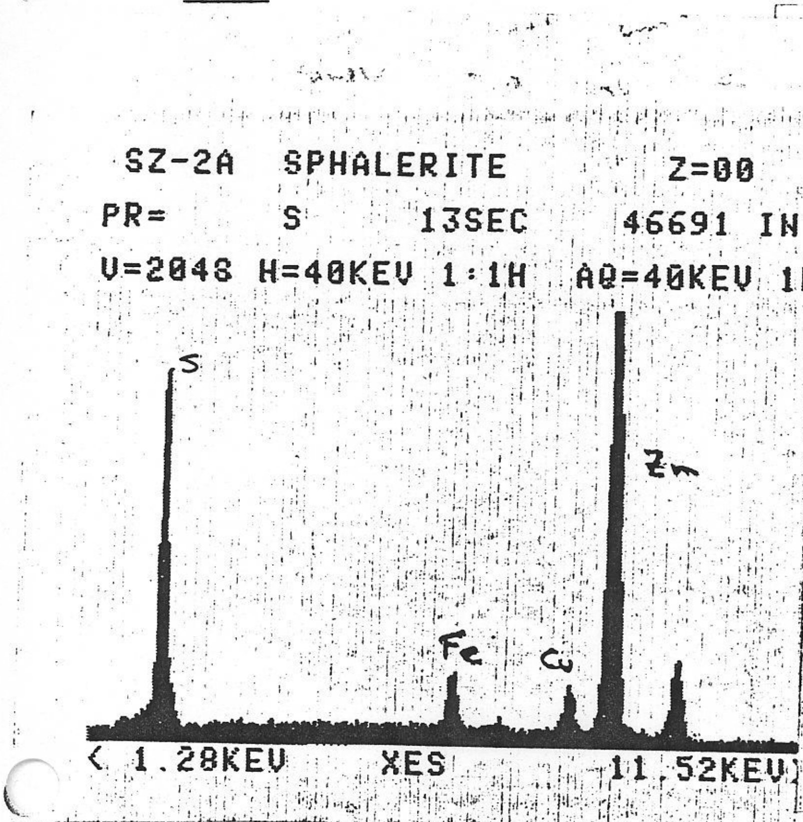
Electrum: trace. Observed only as tiny grains within sphalerite. It is unlikely that these grains will be free-milling and therefore will show in the sulphide concentrate. Although these grains are insignificant in volume as individuals,they are seldom observed optically, and may occur in significant amounts.

Paragenesis:

```
Py  ------        -------
Sp     - ---------  -
Ga          -- - - -- - -- -
Cp              ------- -
Em             ------
_______________________________
           time --
```

Notes: - iron content of sphalerite varies from grain to grain but probably averages from 2 to 3%.
- Electrum composition: Au = Ag.
- Blue "pyargerite" looking grain turned out to be electrum.
- Tetra hedrite may be present.

SZ-2a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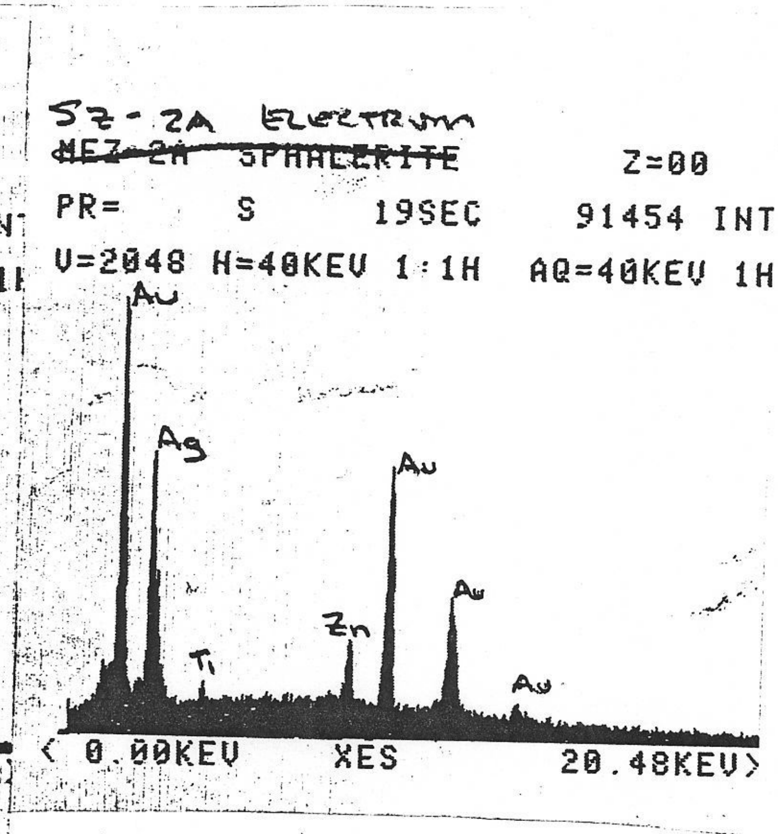
PR= S 13SEC 46691 INT
V=2048 H=40KEV 1:1H AQ=40KEV 1H
S
Fe
Cu
Zn
< 1.28KEV XES 11.52KEV>


SZ-2A ELECTRUM
~~MEZ-2A SPHALERITE~~ Z=00
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V=2048 H=40KEV 1:1H AQ=40KEV 1H
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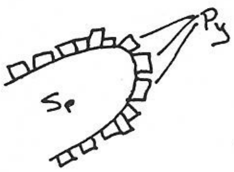
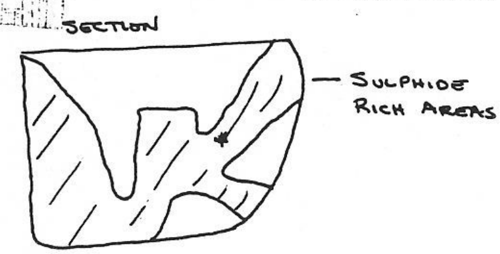
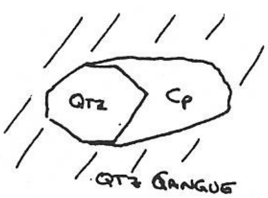
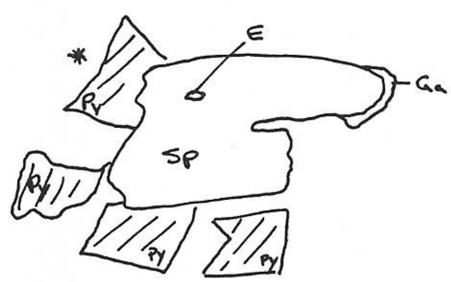
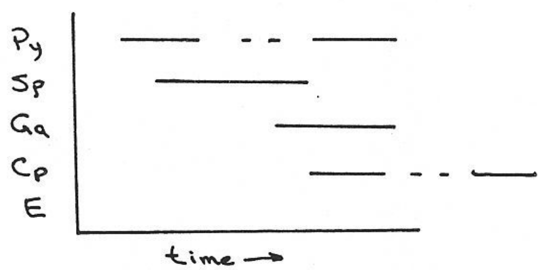
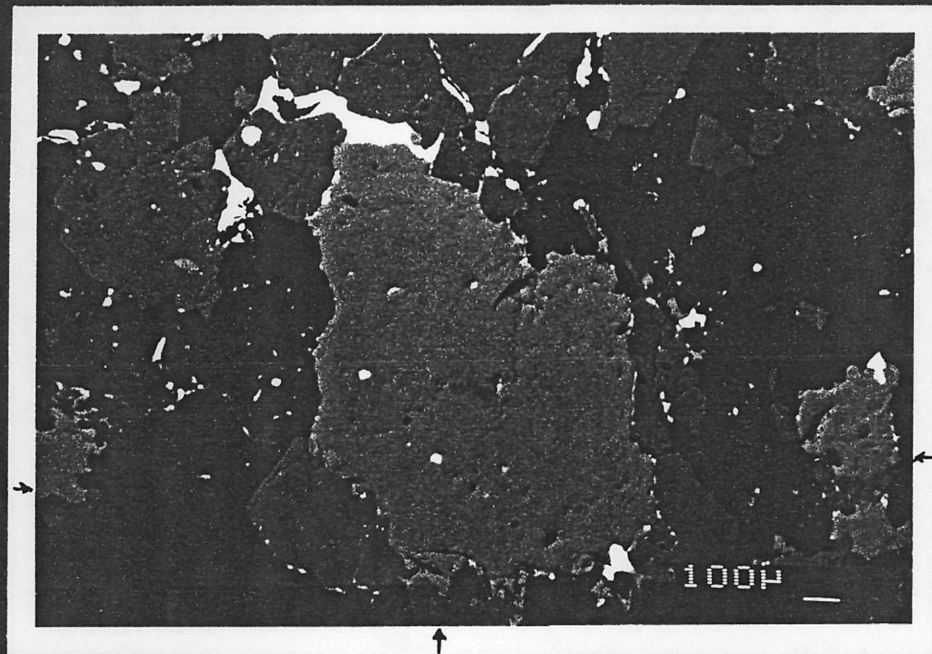

Py
Sp

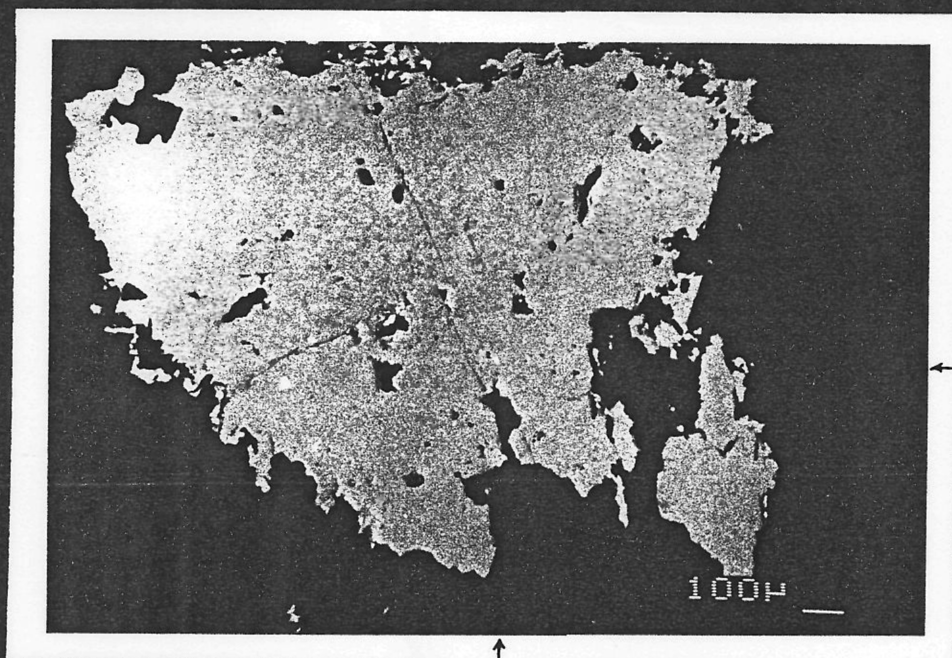

SECTION
SULPHIDE
RICH AREAS


QTZ
Cp
QTZ GANGUE


*
E
Ga
Py
Sp
Py
Py
Py

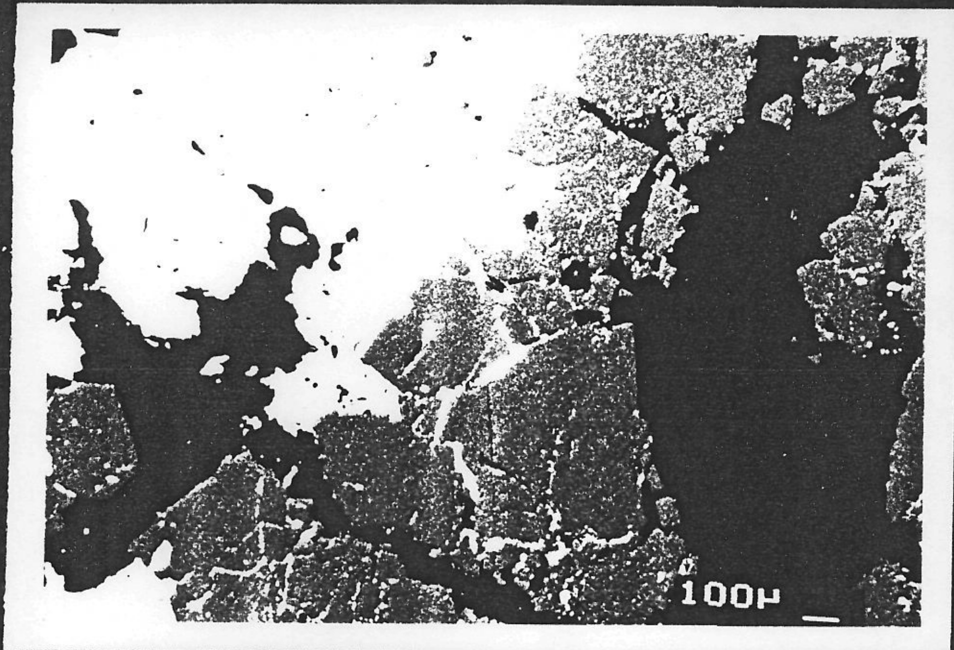

Py
Sp
Ga
Cp
E
time →





SZ-2a top: Sphalerite (light grey) with pyrite (dark grey) and interstitial galena (white). Small white grain, where arrows meet, is electrum, the other white grain is galena.

SZ-3b bottom: Large sphalerite grain with electrum (where arrows intersect) and galena microinclusions.



SZ-1a top: Subhedral pyrite grains with later sphalerite and interstitial/grown galena.

Dago Hi-Grade bottom: Micro acanthite crystals growing on native silver and argentite. Crystals took three weeks to grow on polished surface.

SZ-2b

Rock Description: A white to cream coloured quartz-carbonate rock with prominent micro-comb structure (open spaces). A number of cross cutting sulphide bearing veinlets but orders and relationships are not discernable on such a small specimen. Gold bearing sphalerite appears to be late in the paragenesis. Sulphides, dominately pyrite and sphalerite, occur in anhedral granular aggregates and comprise about 20% of the section by volume.

Sphalerite: 10%. Occurs as large to small irregular grains with up to 4% "exsolved" chalcopyrite. Grains are rough with feathery edges and encapsulate considerable amounts of gangue. It is also intergrown or encloses all other phases prsent.

Pyrite: 10%. Gennerally subhedral, occasionally euhedral, medium to fine grain aggregates. Many grains are extensively fractured. In two dimensions it appears to enclose sphalerite, but not as often as the reverse relationship exists. Intergrowths and enclosures of galena are common, which is somewhat distinctive for this section.

Galena: 2%. Occurs as small subhedral grains, associated with all phases but primarily with sphalerite; either as encapsulated blebs or as a late stage rimming. Galena is not very abundant relative to other zones and sections.

Chalcopyrite: 1%. Occurs entirely as "exsolution" blebs within sphalerite.

Electrum: trace. Relatively abundant in this section. Three types of occurrences were observed: 1) as tiny (8u) grains within sphalerite grains; 2) as fine to quite large grains (40u) interstitial to sulphide grains; 3) as medium grains associated with galena and possibly other silver bearing phases (see photo). Grains associated with galena were distinctly more silver rich.

Paragenesis:

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Py - -------- -
Sp       -------- -
Ga          ------  ---
Em              ------
___________________________
          time →
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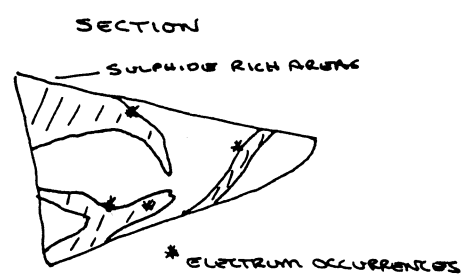
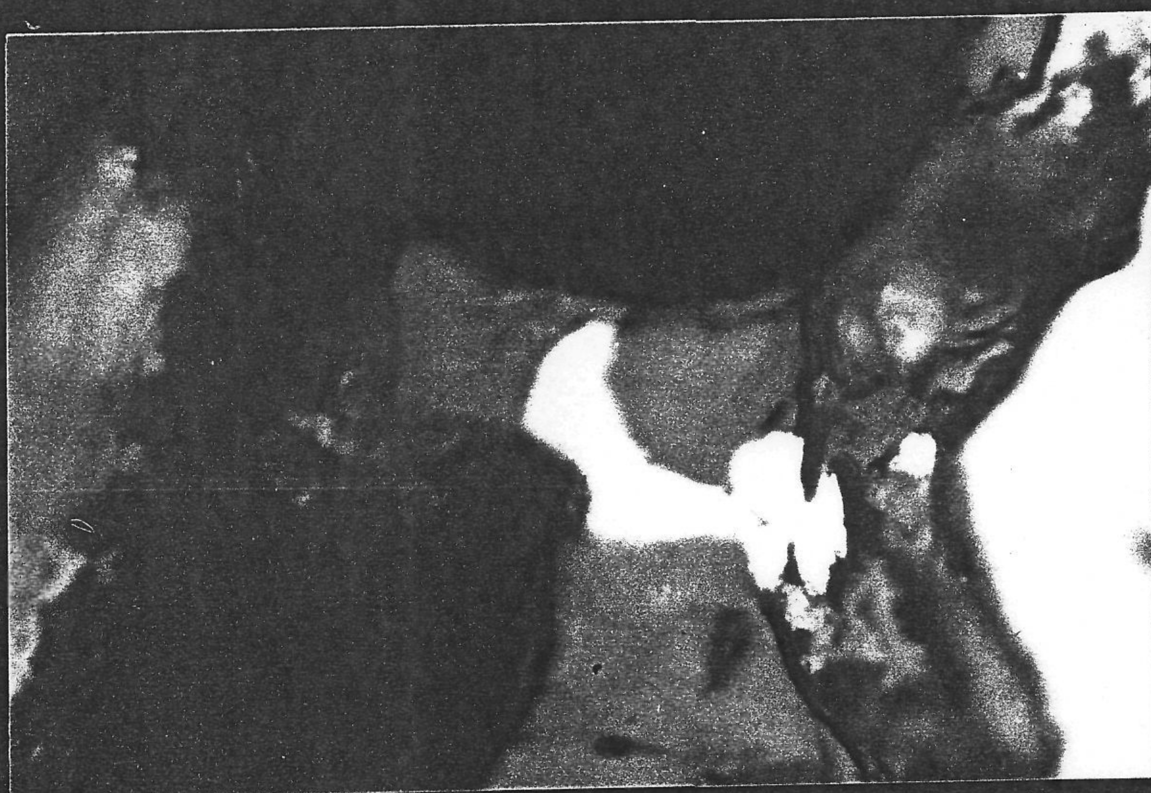
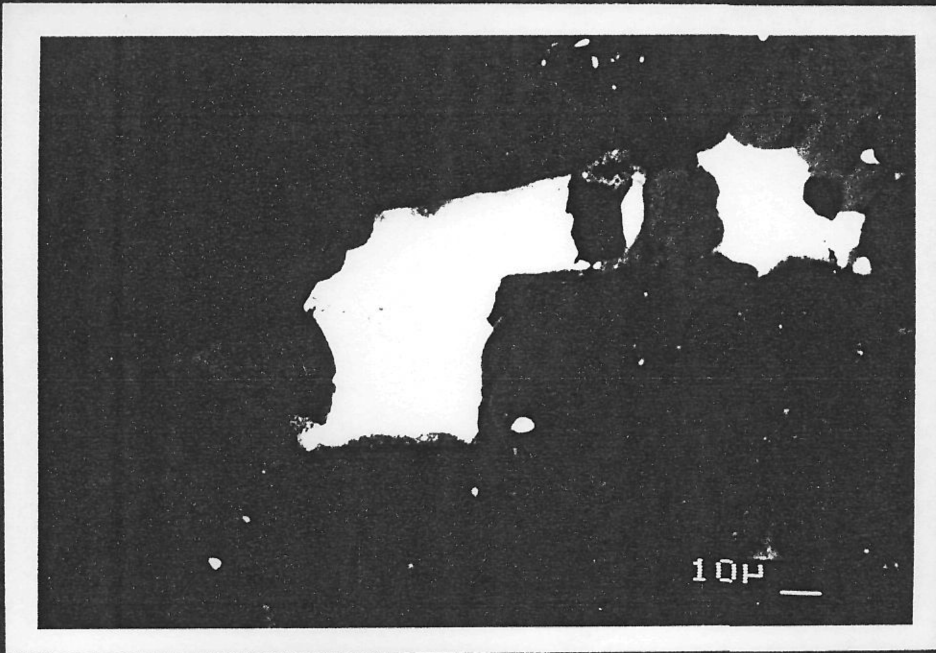


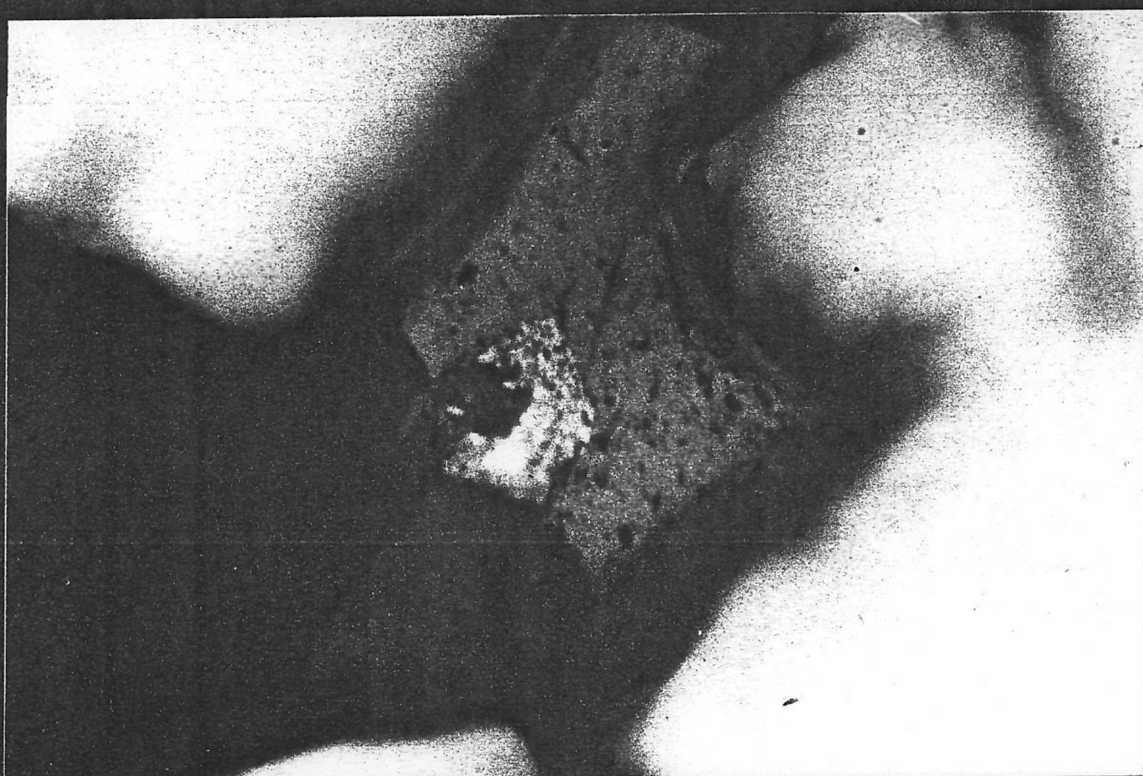
Notes: -iron content of sphalerite is zero.
- -electrum composition varies from $Au_{35}Ag_{65}$ to $Au_{50}Ag_{50}$.
- -blue phase with electrum turned out to be electrum, however SEM backscattered image showed an additional phase on the edge of electrum. The EDS analysis was not totally diagnostic due to size (contamination) and edge effect (beveling) but assumed to indicate native silver and argentite.



SZ-2b top: Intergrown pyrite, sphalerite, galena and electrum. Electrum is the sickle shaped grain in left center.

bottom: Close up of the above electrum grain in sphalerite (400X).





SZ-2b top: Intergrown pyrite, sphalerite, galena and electrum. Electrum is the sickle shaped grain in left center.

bottom: Close up of the above electrum grain in sphalerite (400X).

SZ-3a

Rock Description: Section consists of a single pale green, silicified andesite (?) fragment set in siliceous, sulphide rich matrix. Sulphide content of the fragment is approximately 8%, mostly sphalerite and pyrite. Matrix contains about 17% sulphides, of which 12% is sphalerite. Sulphides tend to occur in clusters or aggregates. In overall appreance this section very much resembles MEZ-1.

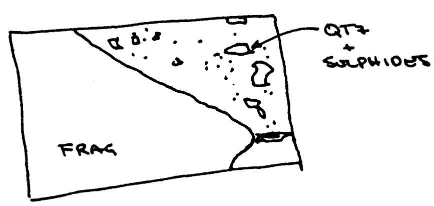
Sphalerite: frag 4%; matrix 12%. Varies in occurrence from coarse irregular aggregates to fine ameoboid disseminations. "Exsolved and intergrown chalcopyrite is a prominent feature, however some grains are copper free suggesting two stages of sphalerite formation. It appears that the copper free stage is later in the paragenetic seguence. Abundant encapsulated gangue and galena is common.

Pyrite: 3%. Evenly distributed in both the fragment and the matrix. Euhedral to subhedral, pyrite is often pitted and frequently encapsulates gangue (quartz).

Galena: 1%. Slightly more present within the matrix as compared to the fragment. Occurs as small irregular blebs, mostly intergrown with sphalerite but some free in gangue as well.

Chalcopyrite: 1%. Occurs almost entirely as "exsolution" blebs and intergrowths with sphalerite - both in the fragment and the matrix, with slightly higher concentration in the matrix.

SECTION:



SZ-3b

Rock Description: Specimen consists of approximately 25%, coarse, subhedral,red sphalerite and minor pyrite set in a matrix of carbonate and silicified lithic tuff.

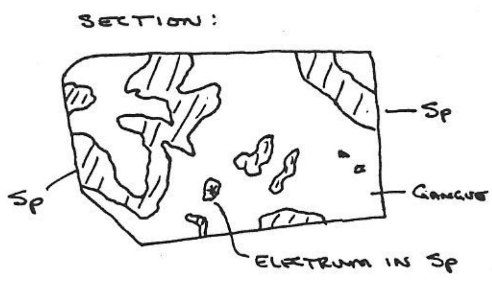
Sphalerite: 25%. Microscopic examination reveals that sphalerite grains have amoeboid shapes with very ragged edges. Typical grains enclose abundant gangue and fine pyrite grains. From 2 to 4% "exsolved" chalcopyrite and a light sprinkle of tiny galena blebs is normal for this section. Three sphalerite grains were observed to contain tiny (<10u) but discreet electrum grains.

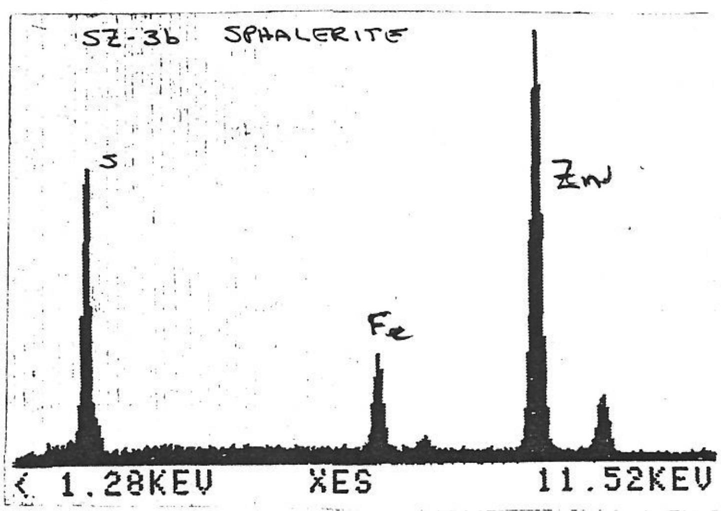
Pyrite: 3%. Generally occurs as euhedral to anhedral, medium sized grains. Overall appearance suggests that pyrite mineralization was much earlier, possibly seperate event, relative to other sulphide mineralization. Some instances where sphalerite appears to replace or partially replace pyrite.

Chalcopyrite: 1%. Virtually all is contained witin sphalerite as "exsolution" blebs or as fine intergrowths with only a few, randomly scattered free grains in gangue. Free grains possess the characteristic highly irregular shape common to chalcopyrite.

Galena: 1%. Occurs mostly as tiny intergrowths with sphalerite. There are a few irregular shaped grains entirely within gangue and some late stage filling along hairline fractures.

Electrum: trace. As very small grains contained within sphalerite.





Notes:
- iron content of sphalerite is 7%.
- matrix carbonate is dominately calcite with minor Fe and Mn components.
- electrum composition is roughly $Au_{.6}Ag_{.4}$.

MEZ-1 Footwall breccia.

Rock Description: Specimen is a fragment supported breccia of pale green, silicified lithic clasts within a sulphide-quartz-carbonate matrix. Matrix is greater than 50% sulphides; dominately sphalerite with lesser pyrite. Sphalerite is deep red in colour.

Sphalerite: 24%. Occurs as aggregates of medium to coarse, irregular grains. A few grain edges are straight but most are highly invaginated, frequently enclosing up to 30% gangue. Enclosed or occluded pyrite is also common. Most grains contain up to 8% "exsolved" chalcopyrite.

Pyrite: 3-4%. Occurs as tiny euhdral disseminations within breccia fragments and as fine to medium subhedral grains within the matrix. Matrix grains are often pitted and corroded.

Chalcopyrite: 2%. Most chalcopyrite occurs as exsolution blebs and intergrowths within the sphalerite but numerous small, irregular grains exist within the gangue as well. Manganiferous siderite intergrown with chalcopyrite was observed in a few instances.

Galena: trace. As tiny specks, mostly within sphalerite.

Friebergite: trace. Two observed occurrences; both as fine grains within sphalerite near areas of concentrated pyrite and chalcopyrite intergrowths. (Optical prop. - Bright, pale blue, isotropic, and very soft.)

Paragenesis:

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Sp          ----------
Py    - -------- -
Cp            -------- -
Fg                  --
______________________________
            time --
```
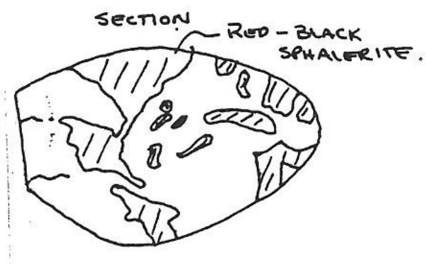
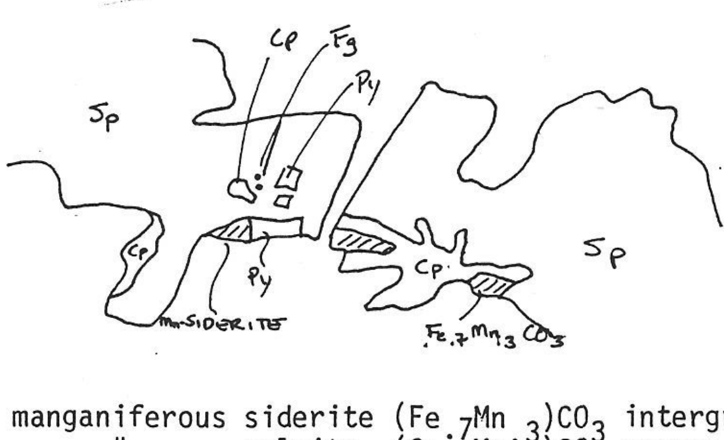





- manganiferous siderite $(Fe_{.7}Mn_{.3})CO_3$ intergrown with Cp.
- " calcite $(Ca_{.9}Mn_{.1})CO_3$ occurs in gangue.

Notes: -iron content of sphalerite 6% and consistant from grain to grain.

MEZ-2

Rock Description: Specimen is a dark semi-massive to massive sphalerite bearing rock. Other sulphides are quite sparse. Minor deformation of the rock is apparent.

Sphalerite: 50%. Occurs in elongated massive lenses and scattered semi-massive whisps (like stato-cirrus clouds) . Textures suggest partial recrystalization under stress. Up to 8% "exsolved" chalcopyrite, and occasional coarse chalcopyrite intergrowths within sphalerite. Entrapped pyrite grains and abundant gangue is common.

Pyrite: 5%. Euhedral to anhedral, fine to medium sized grains occur in small clusters or congregations. Pyrite is frequently pitted or corroded. Chalcopyrite occurs as interstitial filling within some of the pyrite agregates.

Chalcopyrite: 3%. Predominent occurrence is as "exsolution" blebs and intergrowths within sphalerite, but also occurs free within gangue as small iregularly shaped disseminations. Intergrown with the larger of the "exsolution" blebs is a slightly harder (than chalcopyrite) pale pink mineral that is probably pyrrhotite. An EDS scan supports this but the possibility of cubanite or valleriite cannot totally be ruled out. Sphalerite adjacent to the pyrrhotite is not saturated with respect to iron.

Pyrrhotite: trace. See above.

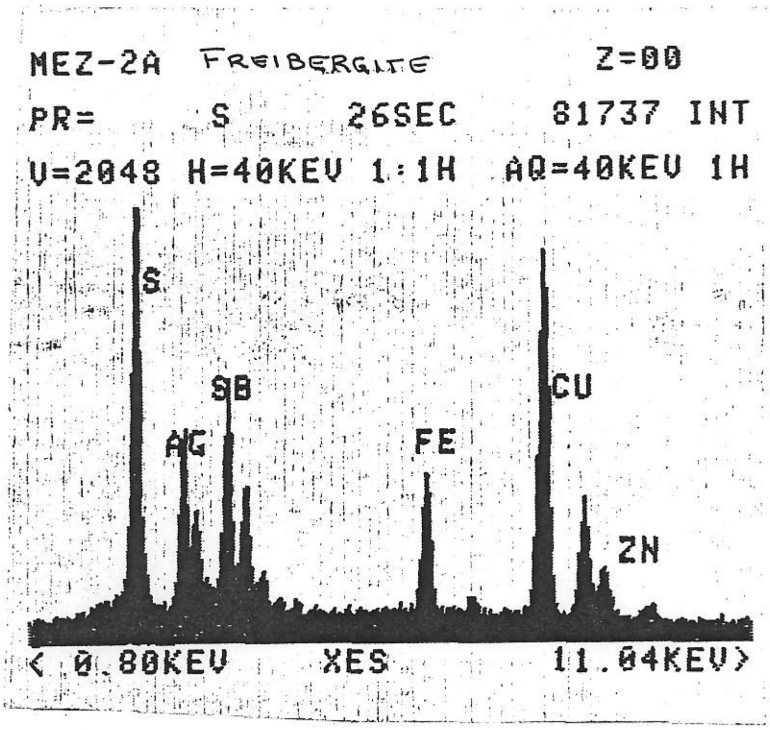
Galena: conspicuously absent.

Barite: trace. Determined by SEM/EDS, tiny whisps of barite were observed rimming spalerite grains along fractures.

Paragenesis:

```
Sp          -------
Py     ----- -
Cp            ----- -
Po              ---
Ba                     ---- -
___________________________
         time --
```

Notes: - iron content of sphalerite is consistant within the section at an estimated 6%.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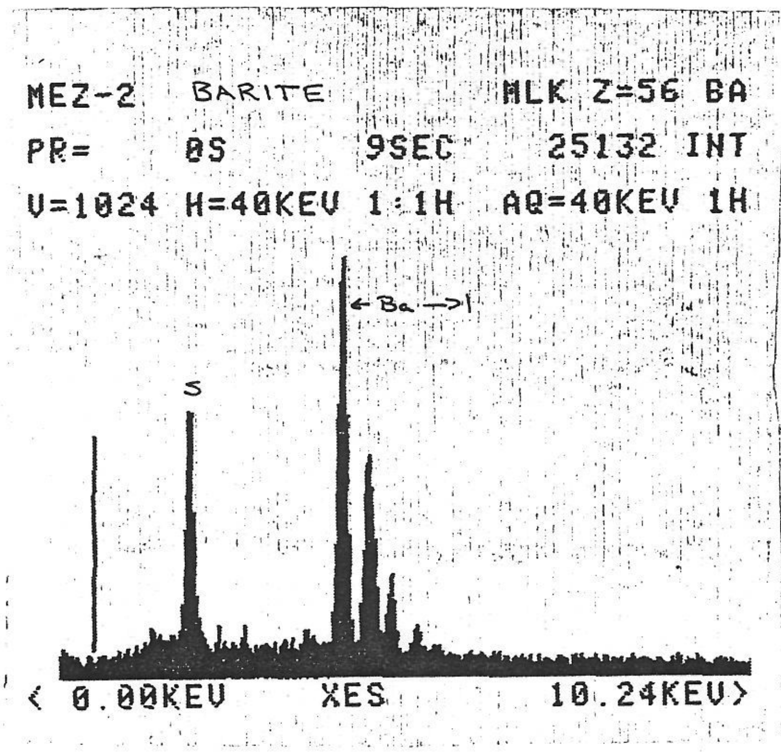
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← Ba →|
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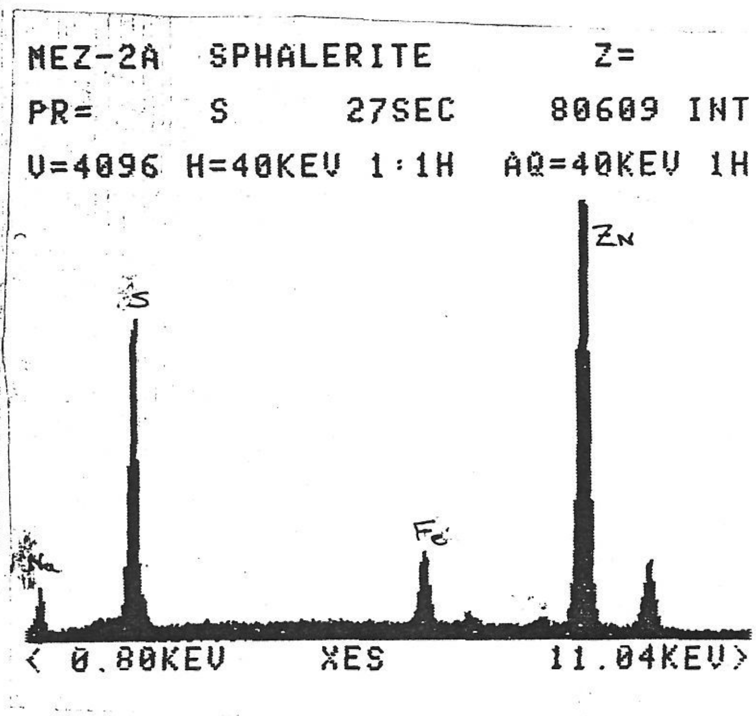
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PR= S 27SEC 80609 INT
V=4096 H=40KEV 1:1H AQ=40KEV 1H
Zn
S
Fe
Na
< 0.80KEV XES 11.04KEV>

DZ-1A (two sections)

Rock Description: Specimen has a strong sulphide banding aspect to it. Coarse euhedral pyrites are set in a dark, siliceous matrix with whispy bands of sphalerite and galena crossing through. Narrow, white quartz veinlets cut across the section parallel to sulphide bands. Sulphides comprise about 35% of the section.

Pyrite: 17%. Occurs as coarse euhedral to subhedral grains arranged in layers. Some grains are quite fractured. Fine anhedral grains occur within sphalerite rich bands. Larger grains have incorporated abundant gangue. Galena, sphalerite and electrum occur as interstitial fillings.

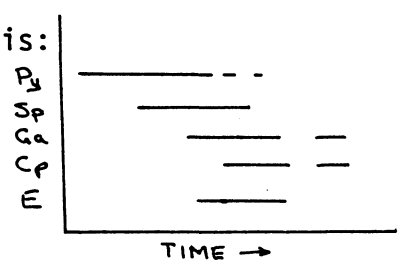
Sphalerite: 9%. Is observed as coarse to fine grained wispy bands, often complexly intergrown with gangue and/or galena. Contains up to 3% included chalcopyrite. Also observed rimming, and filling irregularities within, pyrite grains.

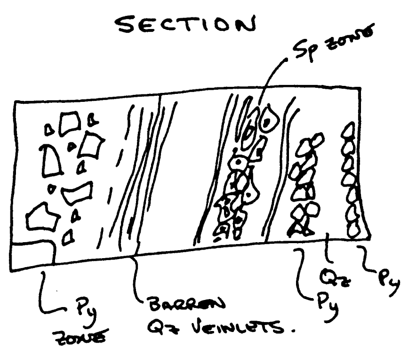
Galena: 4%. Mostly as intergrowths within sphalerite but also as interstitial material in, or overgrowths on, pyrite aggregates. Highly anhedral grains form rims around rounded quartz fragments.

Chalcopyrite: 1%. Occurs as fine "exsolution" blebs or inclusions in sphalerite and galena. There are a few tiny, irregular, discreet grains within gangue.

Electrum: trace. Actually quite abundant - section would probably assay >2 oz Au/tonne. Occurs as fine to coarse grains within pyrite aggregates or along fractures in pyrite. Also resides as rounded grains in galena and as micro-inclusions within sphalerite. An electrum grain within galena has a composition $Au_{30}Ag_{70}$.

Paragenesis:





DZ-2a, b.

Rock Description: Specimens are sulphide rich with bands of sulphides set in a white quartz matrix. Some pyrite is quite coarse.

Pyrite: from 13% (2a) to 50% (2b). The tendency is towards medium to coarse, euhedral to subhedral aggregates, but also comes as finely disseminated anhedral or corroded grains. Pyrite appears to encapsulate numerous other sulphides but this might be due to later sulphide growth on corroded pyrite grains.

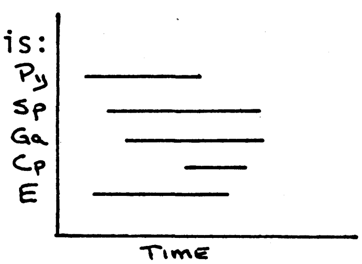
Sphalerite: from 2% (2a) to 13% (2b). Occurs as large sieve like grains to small interstitial fillings. Frequently intergrown with galena and enclosing electrum. Generally about 5% "exsolved" chalcopyrite although in 2a there is some copper free sphalerite.

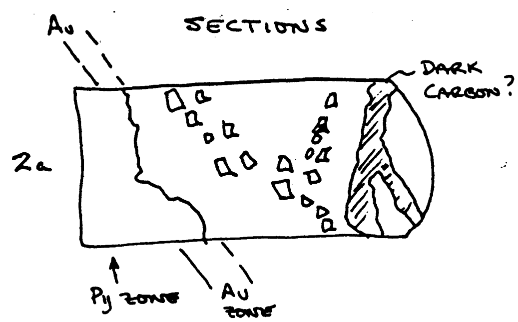
Galena: 1 - 2%. Occurs as fine intergrowths with sphalerite and chalcopyrite and as remobilized interstitial fillings.

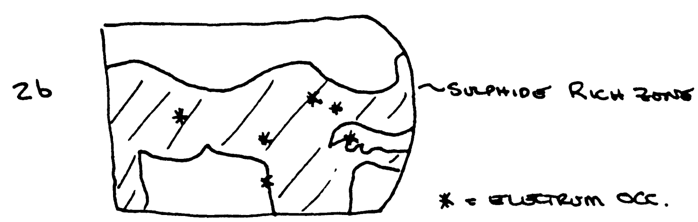
Chalcopyrite: 1%. Almost all within sphalerite. A few tiny discreet grains in gangue.

Electrum: trace. Occurs along pyrite-sphalerite grain boundaries and within spaces between pyrite grains in pyrite aggregates.

Paragenesis:





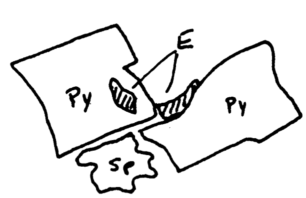


Notes: No Fe in sphalerite.

Pyrite grains show striated faces on broken rock surfaces.

1

2



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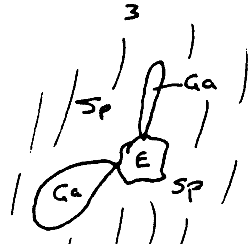


DZ - 3 Fa

Rock Description: specimen is a semi-massive sulphide, consisting of globular aggregates of chalcopyrite and pyrite with lesser sphalerite and galena. There is some metal zonation in that one area of the section is copper rich, another area zinc rich and so on. Sulphides are set in a dark siliceous matrix.

Chalcopyrite: 24%. Occurs as corroded, anhedral to ameoboid masses which encapsulate much gangue and some galena. In some areas the chalcopyrite might best be described as having a net texture.

Pyrite: 10%. Clustered to disseminated anhedral grains of various sizes is the usual mode of occurrence. Some of the pyrite is early as illustrated by crush textures and interstitial fillings of chalcopyrite.

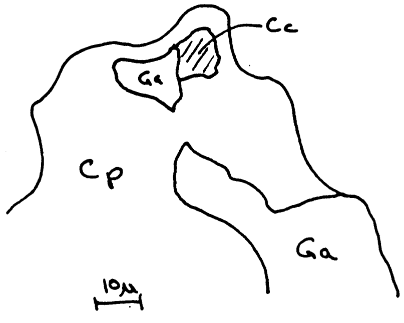
Sphalerite: 6%. Irregular shapes and variable grain size is the only encompassing description for sphalerite. There is a continuum between sphalerite with intergrown chalcopyrite and chalcopyrite with intergrown sphalerite.

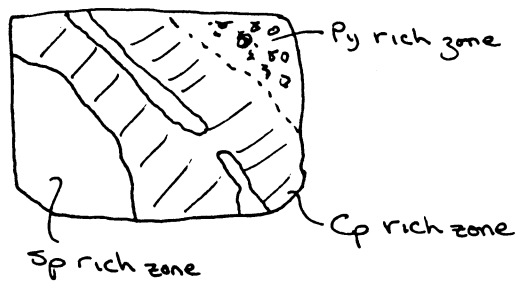
Galena: 2%. Occurs exclusively as coarse to fine irregular shaped inclusions in chalcopyrite and sphalerite.

Argentite: trace. Occurs as small rounded grains within chalcopyrite or along chalcopyrite-galena grain boundaries. At least one observation of argentite may have been native silver.

Chalcocite: trace. Occurred beside galena grains enclosed by chalcopyrite. Because of a dark blue tarnish it was originally throught to be pyargerite but an EDS analysis reveals a low sulpher copper phase.

Notes: Fe content in sphalerite is approx. 2%.





DZ-F1, 2

Rock Description: Specimen is a grey siliceous rock with numerous cross cutting Fe-carbonate and quartz veinlets. A network of fine black fractures gives the section a cloudy appearance. Sulphides are coarse to fine and disseminated throughout the rock.

Pyrite: 6%. Occurs as coarse to fine, subhedral to rounded grains disseminated over the section. Pyrite is more intimately intergrown with other sulphides than was observed in other sections. Pyrite can be found enclosing (?) other minerals, including electrum, but elsewhere it appears corroded and partially replaced by sphalerite.

Sphalerite: 3 - 8%. Displays net textures with abundant incorporated gangue. Could be described as coarse, sieve like grain or as numerous irregular interlocking grains. "Exsolved chalcopyrite to 6%." Some included galena.

Chalcopyrite: 2%. Mostly contained by sphalerite but minor amounts intergrown with galena or silver and as fine fracture fillings.

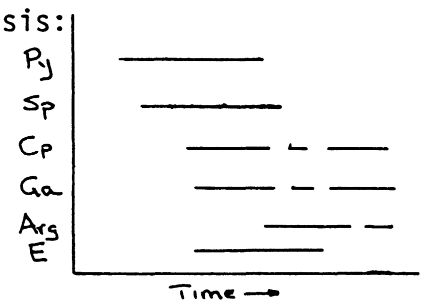
Galena: 1 - 2%. Occurs in a variety of forms from coarse euhedral grains intergrown with carbonate to tiny fracture fillings. Some finely disseminated grains and intergrowths with chalcopyrite and sphalerite.

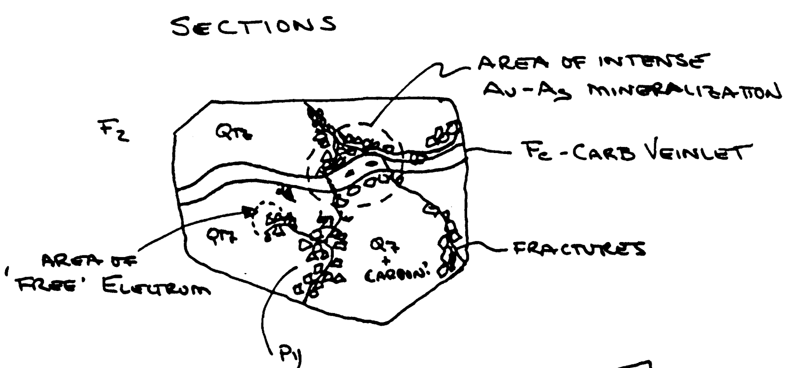
Argentite: trace. Associated with galena and enclosed by pyrite.

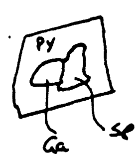
Electrum: trace. Occurs as fine to medium grains enclosed by pyrite and sphalerite.

Native Silver: trace. Observed as fine to coarse irregular grains free in gangue. Often with intergrown chalcopyrite.

Paragenesis:

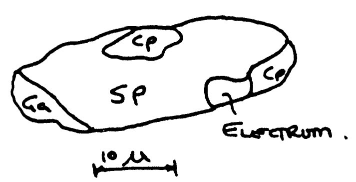


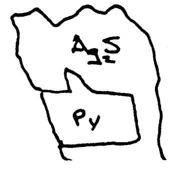


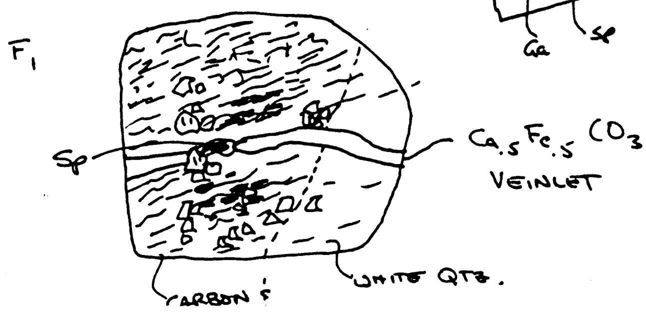


Notes: - Some Mn in carbonates.

- No Fe in sphalerite.







DZ-4A (two sections, one polished thin section).

Rock Description: Sample is a grey-white siliceous rock with a network of black fracture fillings or stylolites. The thin section reveals a rock made almost entirely of variably sized quartz grains with minor sulphides, oxides, carbon (?) and muscovite. Comb and cockade textures indicate open space fillings with late sulphide and carbonate emplacement along fractures. Sulphides make up about 9% of the rock.

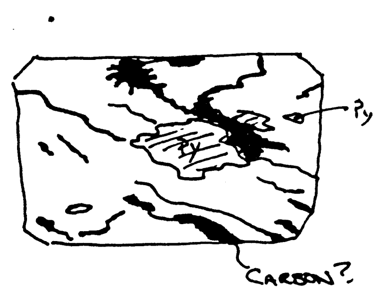
Pyrite: 7%. Occurs as fine to coarse anhedral to euhedral grains and linear aggregates along fractures. An odd, contorted silicate growth occurs between pyrite grains within the fractures. An EDS scan indicates that it is a mixture of muscovite, quartz and a low aluminum Fe-mg silicate such as Celadonite.

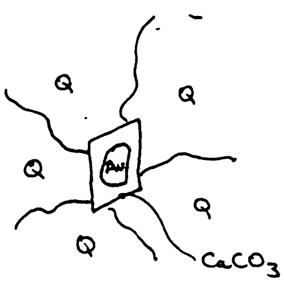
Sphalerite: 2%. More or less finely disseminated, mostly around pyrite within the fractures but also as small isolated anhedral grains in the matrix.

Galena: trace. Only observed under the SEM, galena occurred as micrograins within pyrite and sphalerite.

Electrum: trace. Only a single 6 μ grain was observed. The grain was sitting in a slightly larger, isolated calcite rhomb within a quartz vein.

SECTION





Dago Hi-grade (two sections)

Rock Description: sample is dark and siliceous with about 15% sulphides and numerous vugs lined with quartz crystals. Sulphides are finely disseminated and appear to be fracture controlled.

Sphalerite: 6%. Commonly as coarse to fine anhedral amoeboid grains, either in isolated aggregates or intergrown with other sulphides. Appears to come in two stages: an early stage with up to 6% "exsolved" chalcopyrite, and a later copper free stage. Sphalerite is iron poor or iron free.

Pyrite: 3%. Usually as subhedral grains of various sizes. Generally disseminated throughout the section, occasionally with later sulphides growing around them.

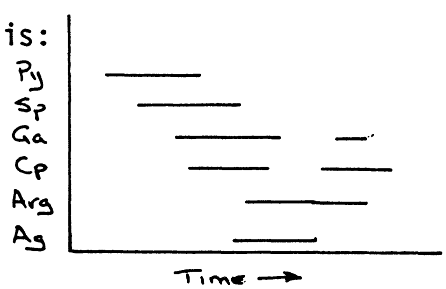
Galena: 3%. As rounded to anhedral grains of variable size, most often with sphalerite. Complex intergrowths with chalcopyrite, argentite and siderite, along small fractures are common.

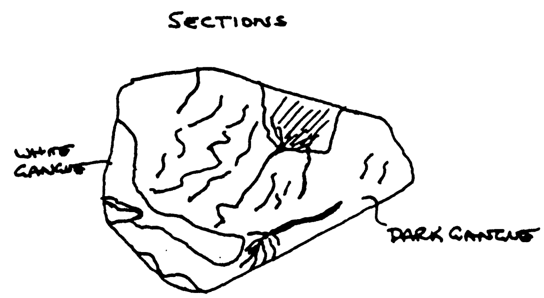
Chalcopyrite: 1%. Occurs as wisps, fracture controlled strands and tiny disseminated grains. Strongly associated with argentite, native silver and galena.

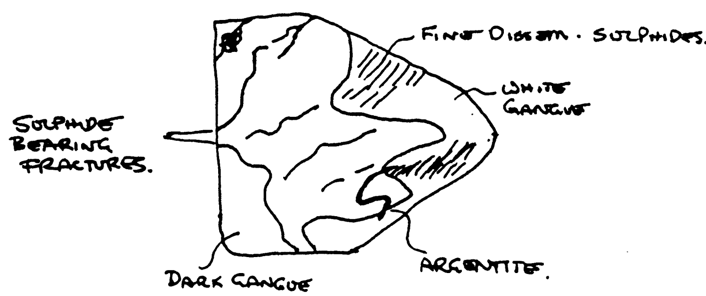
Argentite: 1%. Varies from bright blue to pale greenish white in colour. Occurs in complex intergrowths with galena, siderite and chalcopyrite along narrow fractures. Also occurs as inclusions within chalcopyrite and native silver. Less commonly it is found rimming other sulphides or as interstitial fillings in gangue minerals.

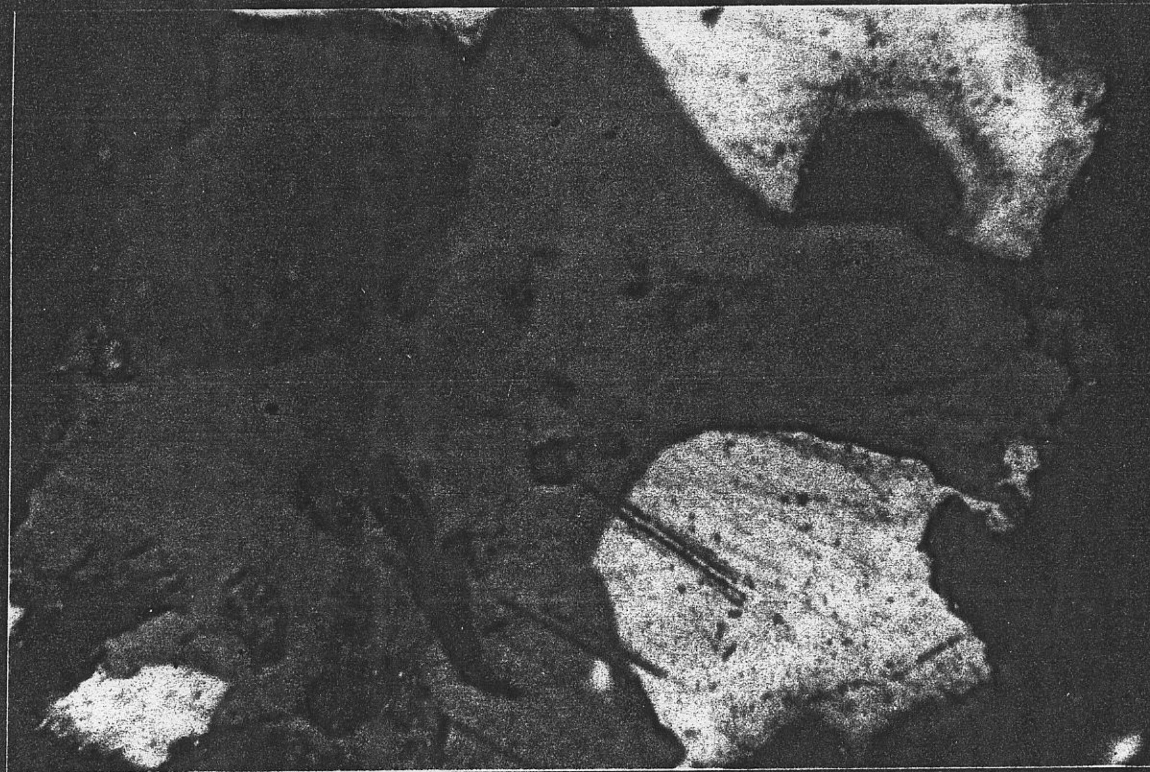
Native Silver: trace. Most often occurs free in gangue as coarse grains with minor inclusions or intergrowths of chalcopyrite and argentite. Frequently takes a yellow tarnish which makes it look like electrum.

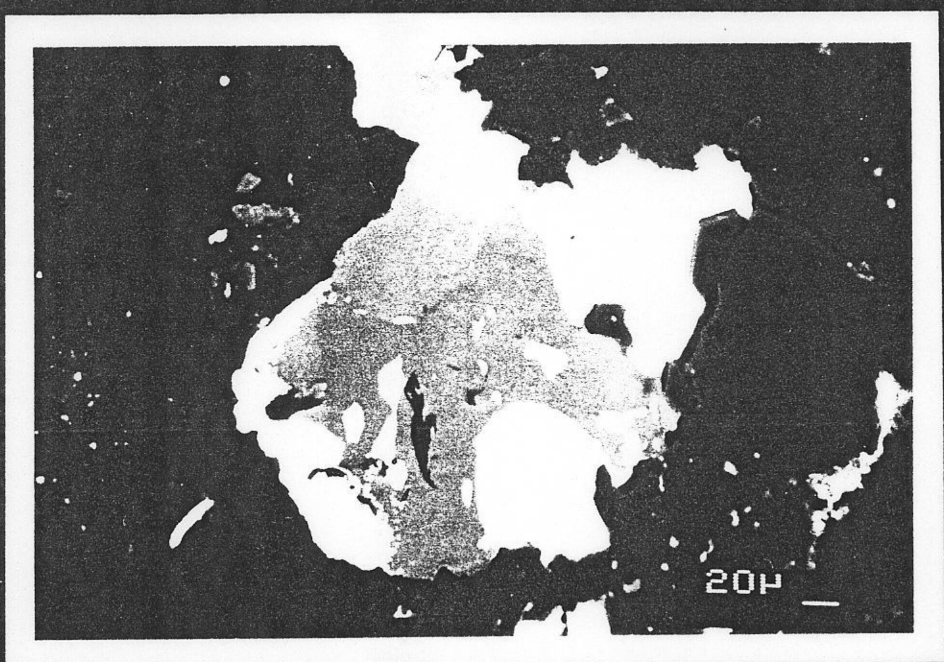
Paragenesis:





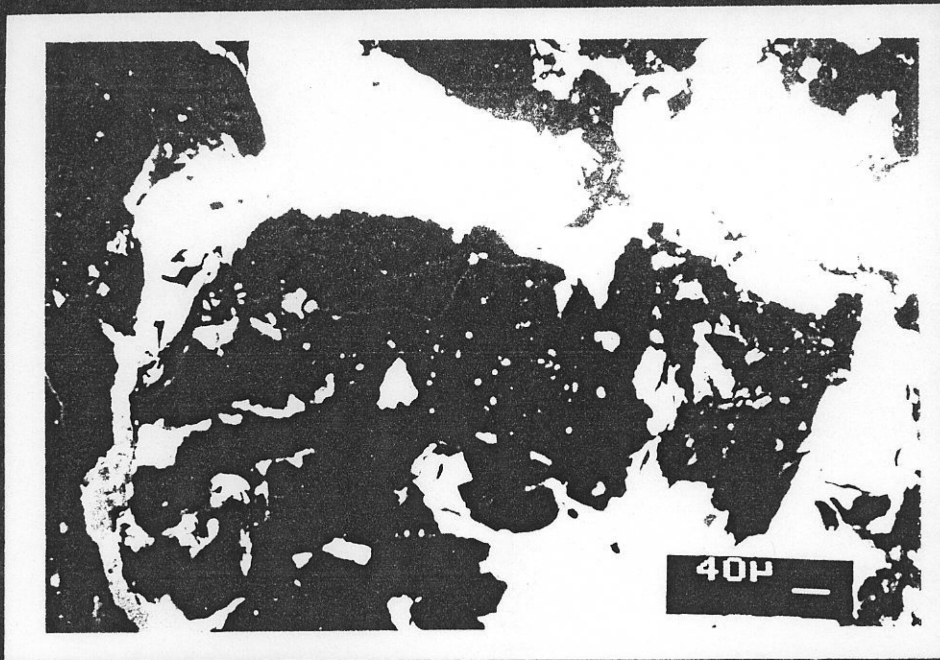


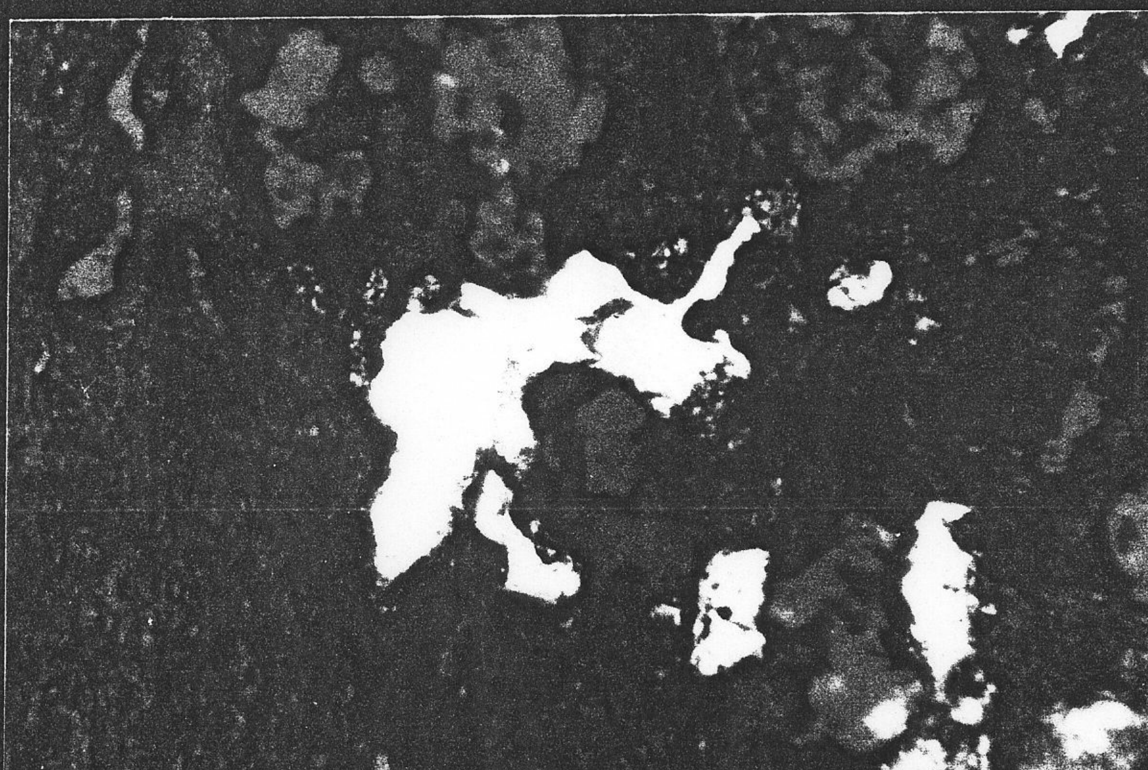




Dago Hi-Grade top: Argentite (speckled blue grey) in chalcopyrite (brown) with sphalerite (purple grey) and galena (silver).

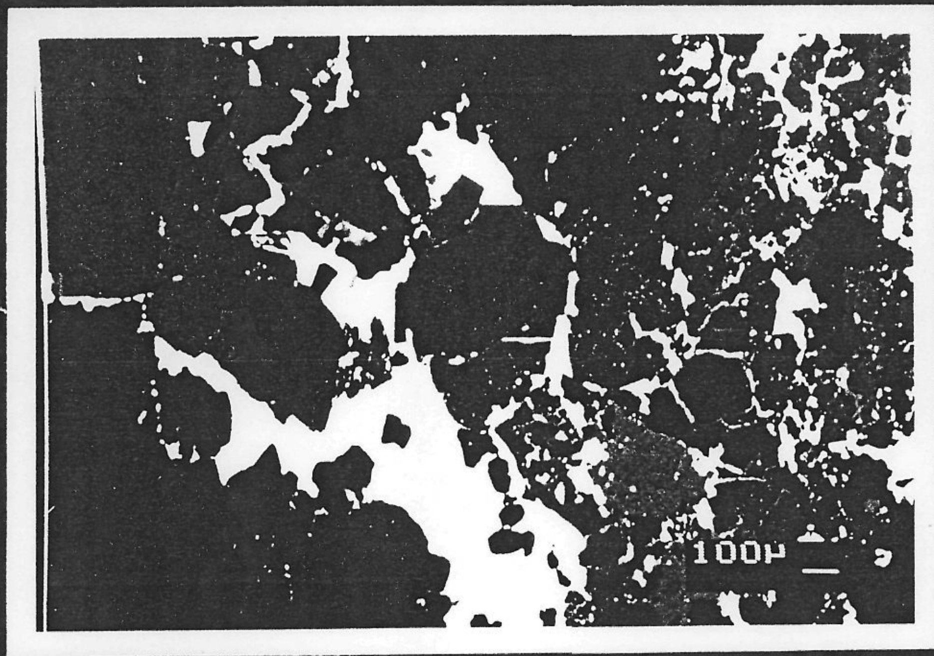
bottom: SEM BSE image of above at slightly larger scale.

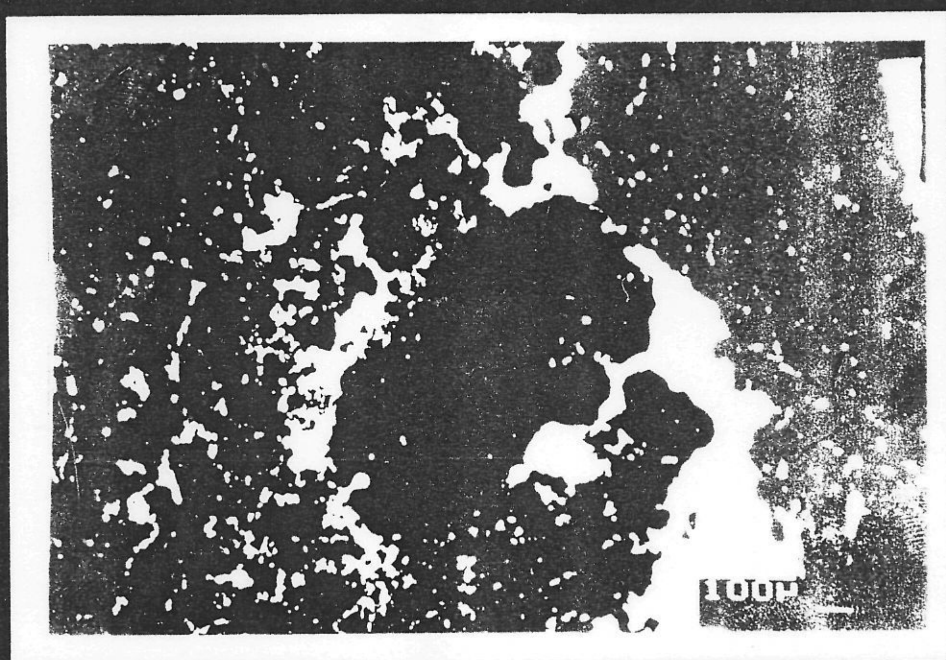




Dago Hi-Grade top: Intergrown gangue (black), pyrite (grey), argentite (light grey) and galena (white).

bottom: Electrum and galena in quartz and carbonate gangue. (320 X).





DZ-1a Top: Galena (white) overgrowth textures on pyrite (dark grey) and sphalerite (medium grey).

Bottom: Galena (light grey) forming around an elliptical quartz grain.

DZ-2a: Pyrite (pale yellow) enclosing sphalerite (purple grey). Note chalcopyrite inclusions in sphalerite and electrum grain on pyrite-sphalerite grain boundary. Top (90X), bottom (320X).