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62° 16' 47" N
133° 14' 29" W

GEOLOGICAL AND MINERALOGICAL INVESTIGATION OF THE METALLURGY OF THE GRUM OREBODY, YUKON TERRITORY

by

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CONTENTS

APPENDIX

Figure 1 - Grum Camp, November 10, 1976.

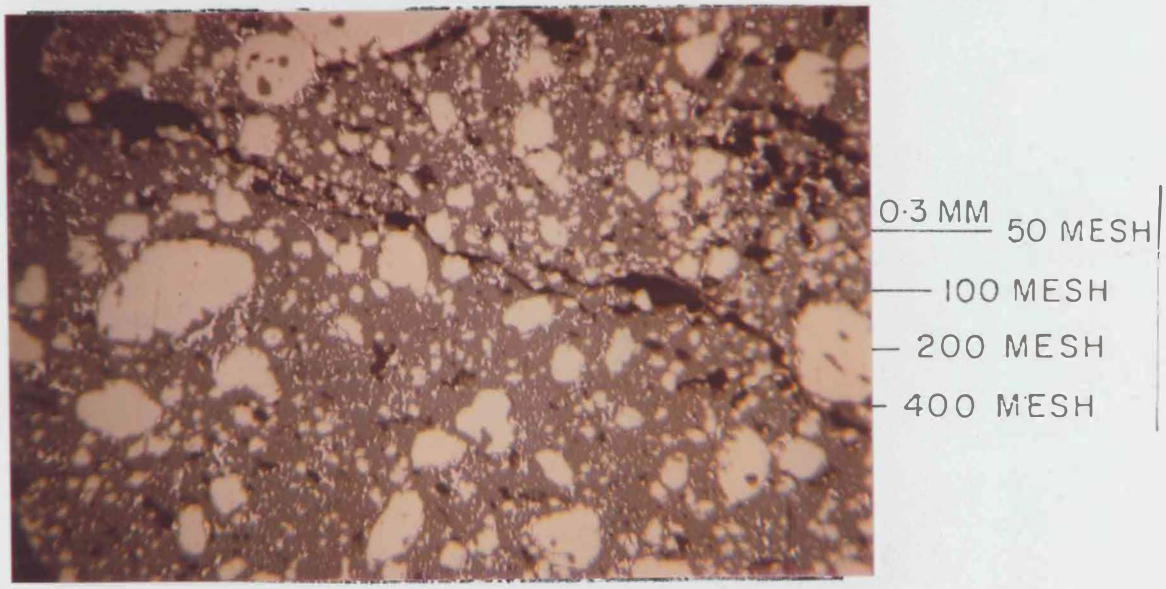

Figure 2 - Photomicrograph of "B"-Type Ore.

Sphalerite=bluish-grey; Pyrite=rounded whitish crystals; Galena=fine silvery-white specks; Oxide=black streaks (cracks)and spots (pits). Features causing the two main metallurgical problems of certain Grum ores are illustrated:

1) extremely fine galena inclusions in sphalerite
2) strong oxidation.

SUMMARY:

The results of most of the metallurgical tests carried out on Grum ores up until November, 1976 were very poor. Extremely fine grinding was necessary, but even with optimum results, lead and zinc losses to the tailings were too high and lead concentrates contained too much zinc. The causes of these problems were unknown.

The present investigation, started in November, 1976, involved detailed examination and sampling of the Grum ores in underground exposures and drill core followed by microscopic examination of 88 representative ore specimens, and microscopic examination of products from the previous metallurgical tests. In addition, samples of different types of ores were collected for exploratory flotation tests. These tests were done by K.V.Konigsmann and K. Stowe of Mattagami Lake Mines Limited, and the results were made available in January, 1977.

As a result of all the above work, two main metallurgical problems have been identified: (1) strong oxidation --- this has probably affected less than 5% of the orebody, and (2) a middlings-producing texture consisting of fine inclusions of galena in sphalerite --- this would appear to be of serious proportions in less than 5% of the orebody.

By coincidence, the ores used for most of the metallurgical testing done up until November 1976 had both of the above deleterious characteristics to an extreme degree and were therefore, not only metallurgically very difficult, but highly unrepresentative of the Grum orebody. The more truly representative ores collected for exploratory flotation tests (above) yielded much better results.

The Grum deposit can be classed as relatively "fine grained", but very little of the ore is as fine as ores from metallurgically-difficult deposits such as those of the Bathurst camp. Whereas Bathurst ores are characterized by extremely fine intergrowths of galena and sphalerite with pyrite, most pyrite at Grum is very clean. Another positive characteristic of the Grum orebody is its very low content of pyrrhotite and marcasite; these can cause oxidation of ores after exposure or during grinding, and promote oxidation of tailings.

The results of this investigation strongly indicate that most of the Grum orebody will give acceptable metallurgical response. In order to confirm this, a large number (750) of specimens have been collected for microscopic study, and several additional large bulk samples of ore-types that are representative of the orebody, have been obtained for further, definitive metallurgical testing.

PURPOSE, SCOPE, AND METHODS OF THIS INVESTIGATION:

Metallurgical tests carried out on Grum ore samples by Lakefield Research of Canada Limited, Noranda Mines Limited, and Mattagami Lake Mines Limited, from November 1974 to November 1976 had variable, but generally poor results. The first tests were done on diamond drill core and some of these gave acceptable results, but most later tests done on bulk samples from underground, yielded very poor results. The main problems encountered were:

(1) much sphalerite and pyrite could not be depressed during lead flotation. This resulted in low-grade lead concentrates with anomalously high amounts of zinc (Pb = 30-45%, Zn = 10-25%).

(2) lead and zinc losses to the flotation tailings were unusually high (Pb = 1% to 1-1/2%; Zn = 1-1/2% to 2-1/2%).

Despite much experimentation, acceptable lead concentrates could not be produced from the bulk samples; lead recoveries were only fair. Good zinc concentrates (Zn = 55-58%, Pb = 1-2%) were produced, but zinc recoveries were poor. The reasons for these metallurgical problems were unknown, but some type of "oxidation" was thought to be the probable cause.

The viability of the remote Grum deposit could depend on its ability to yield saleable, high-value concentrates. Although the first tests suggested that such concentrates might be obtainable, most of the later tests were negative. Even assuming that poor-quality concentrates could be produced economically and sold, it was not possible to commence mill design until the true metallurgical character of the Grum orebody was defined.

In late October, 1976, R.L. Coleman of Noranda and M.D. Rowswell of Kerr Addison asked the writer if he would investigate the causes of the metallurgical problems at Grum.

Three days, November 10 - 12, 1976, were spent in the company of James Paxton of Kerr, at the Grum property. Diamond drill core from 60 drill holes spaced throughout the entire orebody was examined and 154 representative core specimens were collected. Ore exposures in the underground workings were examined. Several types of ore were observed and fourteen ten-kilogram metallurgical samples were collected from eight underground sites. These were the same sites from which bulk samples had been sent in September 1976 to Anvil Mines for blending tests with Anvil ore. The fourteen samples collected by the writer and Paxton were sent to K.V. Konigsmann of Mattagami Lake Mines Ltd. for bench-scale definitive metallurgical tests. Particular attention was given to one underground site, site "B", which had been the source of most of the ore tested to that date. Site "B" was mapped in detail. The ores at "B", as well as at certain other sites, were photographed.

About 115 polished sections were made (by the University of Toronto) of drill core specimens, underground specimens, and of the crushed head samples for the 14 metallurgical tests. A further 25 polished sections were made of the head and test-product samples from two previous metallurgical tests on material from site "B". All polished sections were studied under the microscope by the writer. X-ray identifications of certain minor minerals were made by the Ontario Department of Mines.

Throughout all the above investigations, close contact was kept with K.V. Konigsmann and K. Stowe of Mattagami, who clarified for the writer many of the metallurgical characteristics and problems of the Grum ores, and with John Carrington of Kerr Addison, who supplied the writer with geological sections and drill-hole logs.

GENERAL GEOLOGY AND MINERALOGY OF THE GRUM OREBODY

Stratigraphy and Structures

The Grum deposit has approximate ore reserves of 30 million tonnes averaging about 4% lead and 7% zinc, based on preliminary calculations. The geology of the deposit is described by W.M. Sirola[1], as follows:

"The Grum structure --- is a crudely "S" shaped fold 1200 m long, 330 m wide, and 330 m in vertical amplitude. The fold structure strikes Northerly and has an apparent plunge North-westerly of 8°-10°.

The main sulphide-bearing zone consists of at least three layers which locally subdivide into bands of variable Pb+Zn grade. The enclosing rocks were originally marine sediments which have been metamorphosed to phyllites. Interbedded with the phyllites are chloritic members which are thought to be volcanic in origin.

Deformation of the deposit took place in pre-Devonian time as a result of regional metamorphism. Faulting, as inferred from diamond drilling, suggests the presence of a thrust near the bottom of the mineralized zone and some high-angle faulting above the thrust on which relative movements are unknown at the present time."

Figure 3 is a generalized cross section of the Grum deposit at 70W, which is near the upper, east end of the orebody. On this section, the orebody is readily divided into four components, 3 North

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[1] Sirola, W.M., 1975: The Grum Deposit: Western Miner, Dec. 1975, p.9.

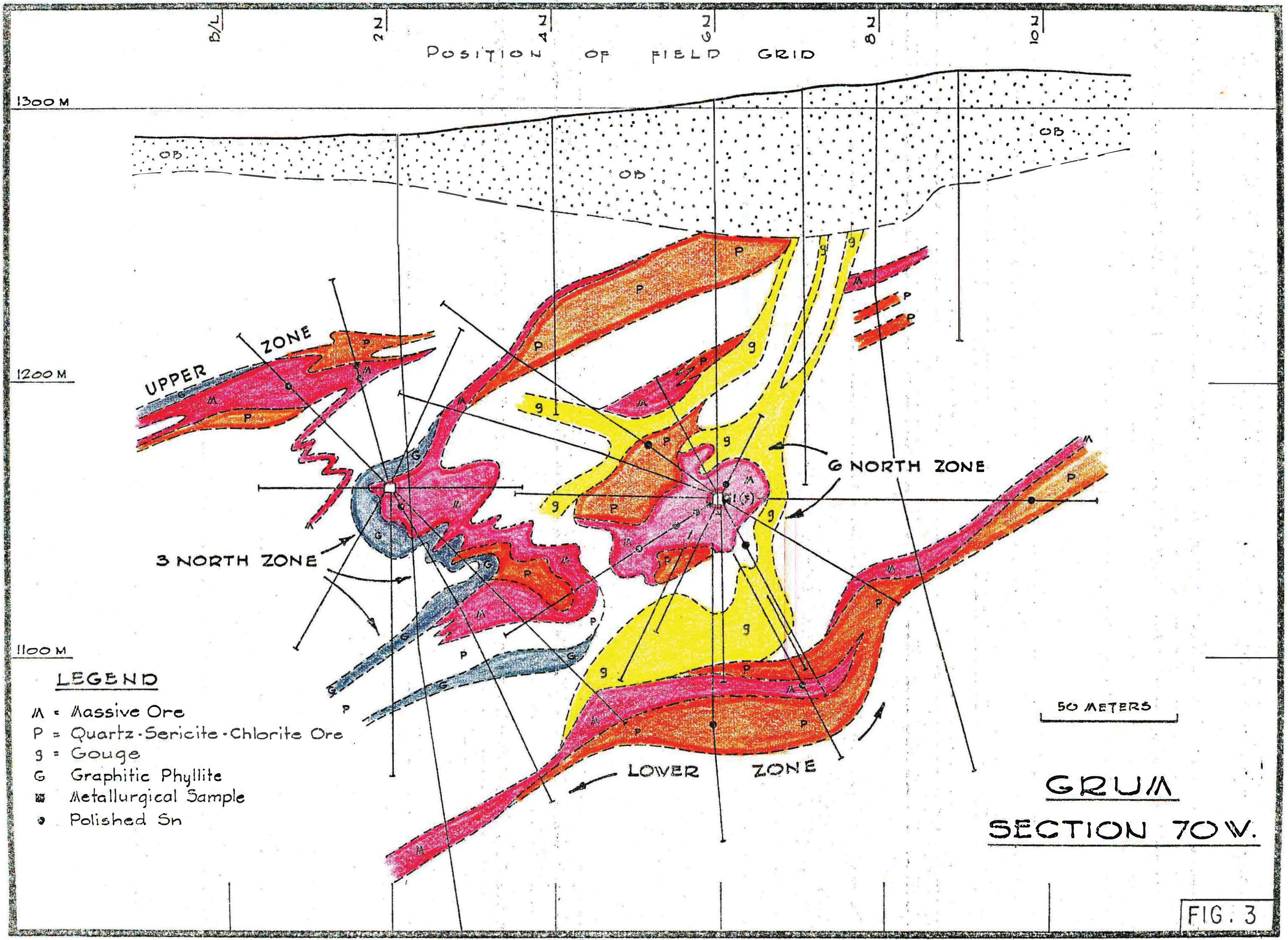

B/L
2N
4N
6N
8N
10N
POSITION OF FIELD GRID
1300 M
1200 M
1100 M
OB
UPPER ZONE
3 NORTH ZONE
6 NORTH ZONE
LOWER ZONE
P
g
G
Λ
50 METERS
LEGEND
Λ = Massive Ore
P = Quartz-Sericite-Chlorite Ore
g = Gouge
G Graphitic Phyllite
▪ Metallurgical Sample
• Polished Sn
GRUM
SECTION 70W.

FIG. 3

Zone, 6 North Zone, Upper Zone, and Lower Zone. On some other sections, the 4-fold division is not as distinct. Because of the extreme folding and segmentation by faulting, geological interpretation (based on drill hole data) is very difficult. Sirola states (above) that there are at least three distinct ore bands, but these may have been contiguous previous to folding and faulting.

"Distal" massive sulphide deposits such as Grum are believed to have precipitated from heavy, hot, metal-laden brines that issued from submarine fumaroles and were ponded in sea-bottom depressions. Low-grade ore forms in the sea-bottom muds due to their impregnation by the hot, metalliferous brines. Once the brines have cooled sufficiently to become saturated, a massive sulphide blanket precipitates on the low-grade muds. The major two-fold division of ore-types at Grum is readily apparent (Figure 3).

Knowledge of the various types of ores and host-rock units is very important to this study because ore-textures, which determine metallurgical responses (see below), appear to be stratigraphically-controlled, and therefore related to the depositional history. As interpreted by the writer from studies of the Grum logs and cross-sections (Figure 3), the over-all stratigraphic sequence (now highly disrupted by folding and faulting) is as follows:

TOP	PHYLLITES	
	GRAPHITIC PHYLLITE (generally 1-20 meters thick)	- graphite is indicative but is absent in places.
	MASSIVE SULPHIDE ORE (generally 1-20 meters thick)	- high Pb at top - high Ba at or near top but Ba does not occur in all localities - thick pyrite bands top to middle - high quartz towards bottom
	SILICEOUS SERICITIC ORE (generally 1-10 meters thick)	- sulphide bands, lenses, and blebs decrease downward
BOTTOM	PHYLLITES	

The siliceous sericitic ore at Grum represents metamorphosed sea-bottom muds and the massive sulphide ore represents the overlying blanket precipitated from metal-rich, hot brines (above). The graphitic phyllites are metamorphosed carbonaceous muds that were deposited on the massive ore after fumarolic activity ceased.

The strongest faults observed by the writer are: (1) two major steeply-dipping, wide gouge zones that straddle the 6 North Zone in the vicinity of 70W (Figure 3). Massive sulphides of the 6 North Zone have been strongly deformed during folding and during movements on these faults. Some high Pb+Zn±Ba layers within the massive sulphides, such as those at metallurgical site "F", have been granulated and later oxidized by groundwater circulating along the faults (see Figures 28, 29). These faults are believed to have affected the orebody mainly between sections 69W and 71W (pers. comm. with J. Paxton).

(2) A major, highly compressional fault along the top of the 3 North Zone which follows the contact between the massive sulphides and the less competent overlying graphitic phyllites. Two segments of this fault are clearly seen at metallurgical site "B" on section 72W (Figure 32a, b). Movements on this fault are believed to have caused granulation and recrystallization of some "B" ores; the fault also allowed influx of groundwaters and oxidation of the "B" ores.

Ore Types and Their Relative Abundances

Following are the main types of ores at Grum, and the estimated percentages of each:

Type of Ore		Estimated %
M	= structureless massive sulphide (sulphides > 75%)	
MB	= banded massive sulphide (galena-sphalerite & pyrite bands)	15%
Mpy	= high-pyrite massive sulphide (brittle bands)	
Mb	= barite-rich massive sulphide (soft bands)	10%
M_Q	= quartz-rich massive sulphide (hard bands)	20%
MV	= vuggy massive sulphide (granulated±baritic bands)	7%
MI	= flow massive sulphide (round inclusions)	2%
MX	= brecciated massive sulphide	<1%
P	= siliceous-sericitic-chloritic ore (mostly medium to low grade; underlies the massive sulphides)	
	P - medium grade	20%
	P - low grade	25%

Top: MV (oxidized); MBV; Mb; MX; M

Bottom: Mpy; M_Q; MI; P(high grade); P(low grade)

Figure 4 - Types of Ores at Grum

Mineralogy

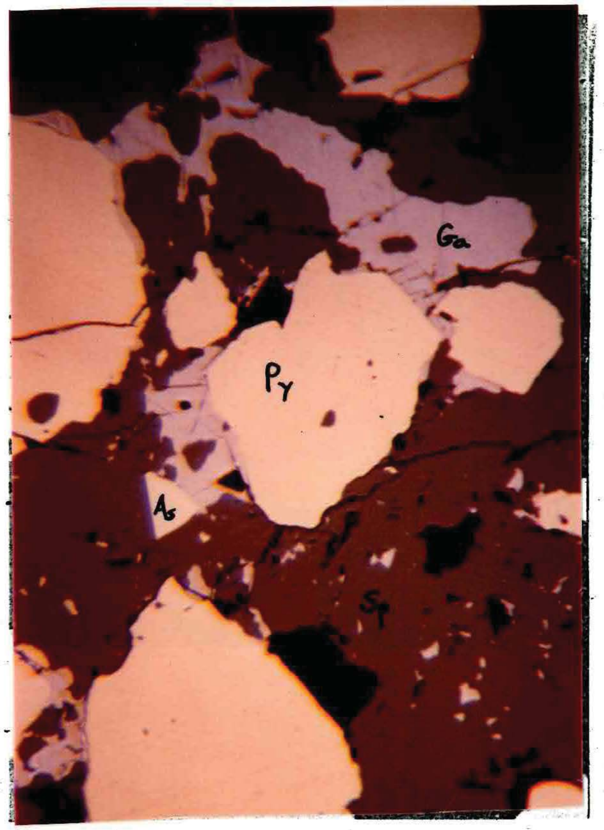
Sphalerite, galena, and pyrite (+ very minor marcasite), are the only abundant metallic minerals at Grum. All these are most abundant in the upper (stratigraphic) massive sulphide portion of the orebody. Sphalerite is invariably more abundant than galena; the average galena : sphalerite ratio for the entire orebody is approximately 2:5.

Minor minerals at Grum are chalcopyrite, arsenopyrite, tennantite, pyrrhotite, and magnetite. Native gold was observed in two of 88 sample sites. The following table gives the abundances and characteristics of these minerals in polished sections from 88 representative sample sites throughout the orebody.

TABLE I - Minor Minerals of the Grum Orebody

MINERAL	ABUNDANCE IN THE 88 SITES	TYPICAL OCCURRENCE
Chalcopyrite $CuFeS_2$	77 sites, tr-7% commonly 1/4-1/2%	common in all types of ores; interstitial to pyrite (Figure 8); veinlets; exsolution blebs in sphalerite (Figure 11).
Arsenopyrite $FeAsS$	64 sites, tr-5% commonly tr-1/2%	occurrence similar to pyrite (Figures 5,6,8,11,12).
Tennantite $(Cu,Fe,Zn,Ag,Hg)_{12}(As,Sb)_4S_{13}$	19 sites, tr-3% commonly tr-1/4%	mostly interstitial to pyrite crystals and in microveinlets (Figures 8, 12)
Pyrrhotite FeS	10 sites, tr-35% only 4 sites >1%	tiny blebs in pyrite; replacing pyrite or marcasite (Figure 13)
Magnetite Fe_3O_4	8 sites, tr-15% ≥1% at 6 sites	isolated crystals, generally with pyrite (Figure 9)
Marcasite FeS_2	8 sites, 1-5%	very fine crystal clusters and rims replacing pyrite; in 2 cases partly replaced by pyrrhotite
Native Gold Au	2 sites, each with one 600 mesh gold bleb	blebs occur in association with tennantite and interstitial to pyrite

PHOTOMICROGRAPHS OF THE THREE MAIN ORE-TYPES



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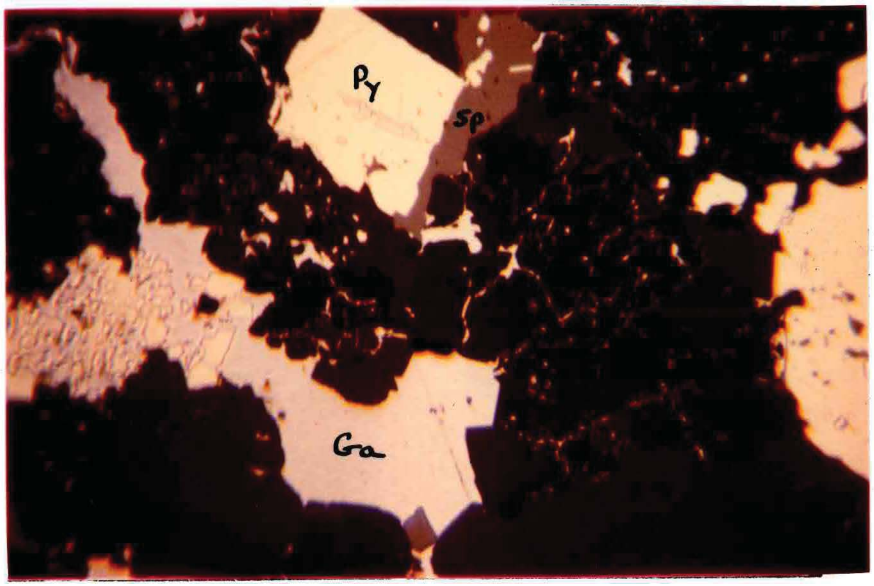
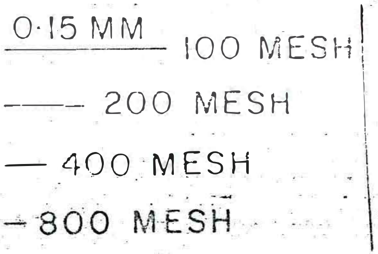




Sp = Sphalerite
Ga = Galena
Py = Pyrite
As = Arsenopyrite
Dark Grey = Gangue

Figure 5 - Typical Massive Sulphide Ore (M).

Note clean pyrite; galena included in sphalerite; minor arsenopyrite. Black lines and spots are cracks and pits in polished section.

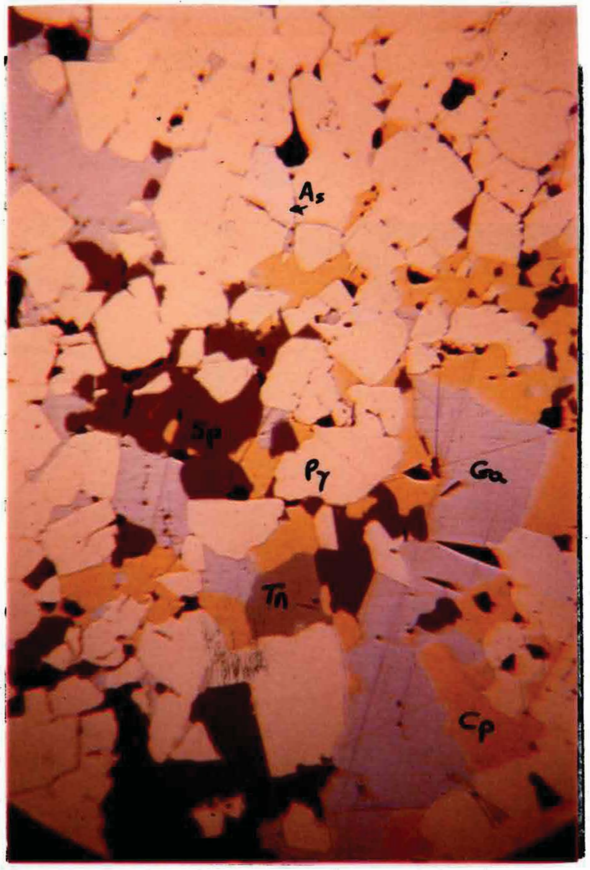
Figure 6 - Typical Quartz-Rich Massive Sulphide Ore (M_Q).

Large dark grey patches are quartz, smaller black ones are pits in polished section.

Figure 7 - Quartz-Sericite-Chlorite Ore (P)

Most galena and most sphalerite occur in coarse grains but some very fine galena is interstitial to gangue minerals (dark grey) and included in pyrite.

PHOTOMICROGRAPHS OF VARIETIES OF MASSIVE SULPHIDES



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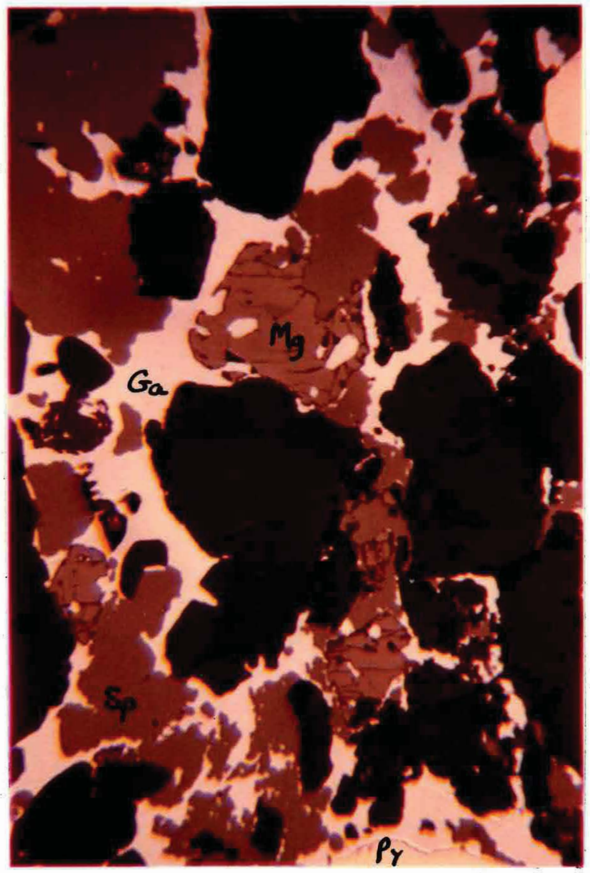

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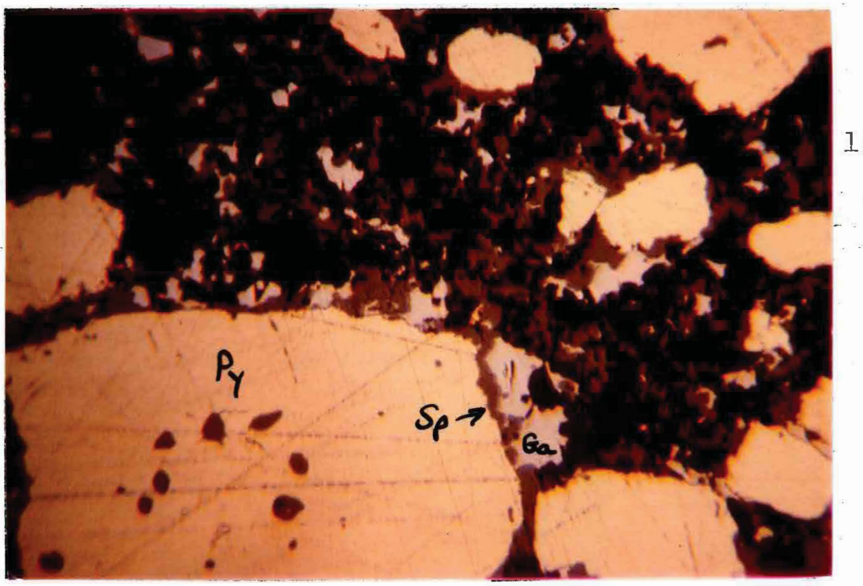
—— 200 MESH

— 400 MESH

- 800 MESH



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Sp = Sphalerite
Ga = Galena
Py = Pyrite
Cp = Chalcopyrite
As = Arsenopyrite
Tn = Tennantite
Ba = Barite
Po = Pyrrhotite
Mg = Magnetitie

Figure 8 - High-Pyrite Massive Sulphide Ore (Mpy).

Note interstitial occurrence of sulphides including chalcopyrite, tennantite.

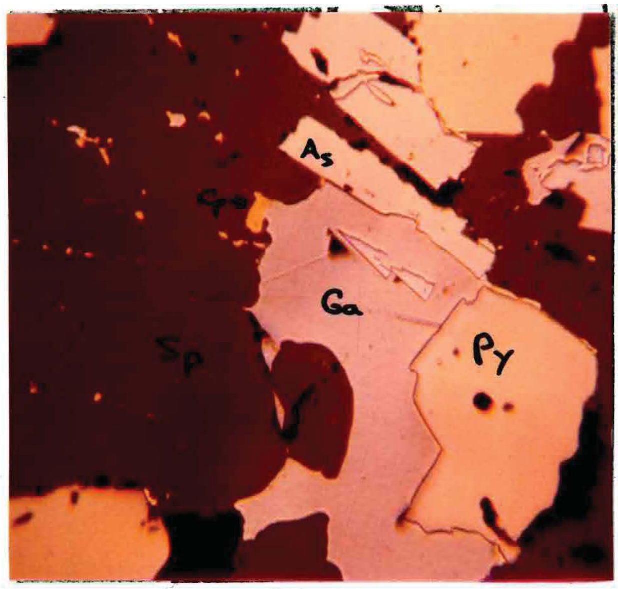
Figure 9 - Baritic Massive Sulphide Ore (Mb).

Dark grey grains are barite; cracked medium-grey grains are magnetite.

Figure 10 - Massive Vuggy Granulated Ore (MV).

Dark grey patches are gangue; black spots are pits (vugs).

PHOTOMICROGRAPHS OF SOME MINOR MINERALS



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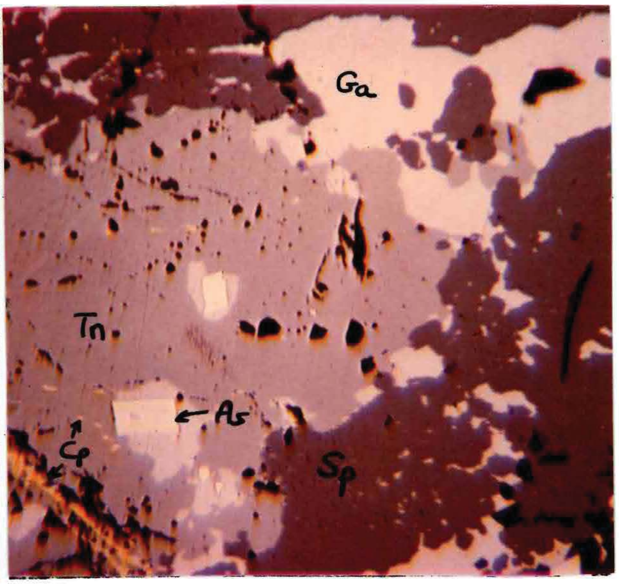

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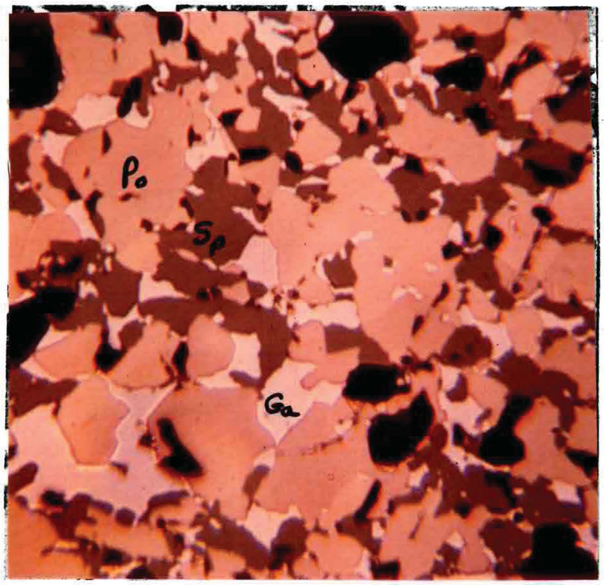

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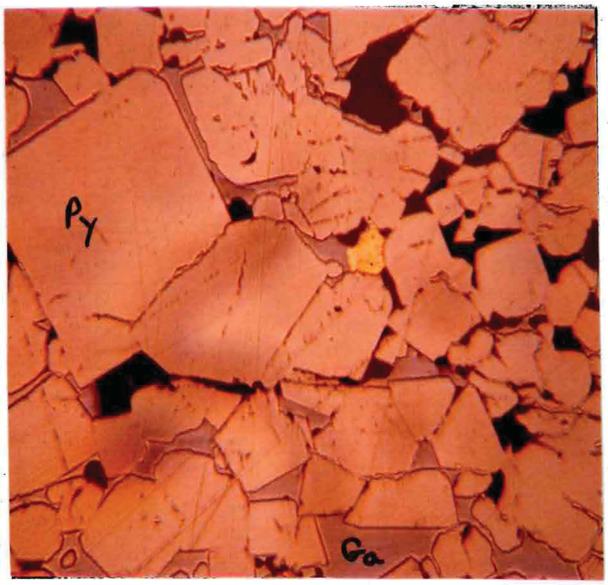

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200 MESH
400 MESH
800 MESH

Figure 11 - Arsenopyrite Crystals in Massive Sulphide Ore.

Note exsolution blebs of chalcopyrite in sphalerite.

Figure 12 - Tennantite in Sphalerite in Massive Sulphide Ore.

Note galena-arsenopyrite inclusions and chalcopyrite blebs and veinlet in tennantite. The high mercury content of the Grum orebody (Table III) is due to the widespread occurrences of tennantite, which may also carry much of the silver.

Figure 13 - Pyrrhotite in Massive Sulphide Ore.

The pyrrhotite has probably replaced pyrite.

Figure 14 - Native Gold in High-Pyrite Massive Sulphide Ore.

METALLURGICAL CHARACTERISTICS OF THE ORES

Galena-In-Sphalerite Middlings Texture (Ga/Sp).

Description and Classification. In the Grum deposit, galena is almost invariably included in larger sphalerite grains. In only a very minor number of polished sections studied, both galena and sphalerite are coarse grained (Figure 15); in this case the two minerals would be easily separated during grinding. At the other extreme are metallurgically difficult ores such as those at site "B" (Figures 2, 21) in which galena inclusions in sphalerite are extremely fine (much < 1500 mesh) and it is therefore impossible to cleanly separate the two minerals on grinding. The main result is unacceptable levels of zinc in the lead concentrates. Fortunately, such ores are as rare as the very coarse ores.

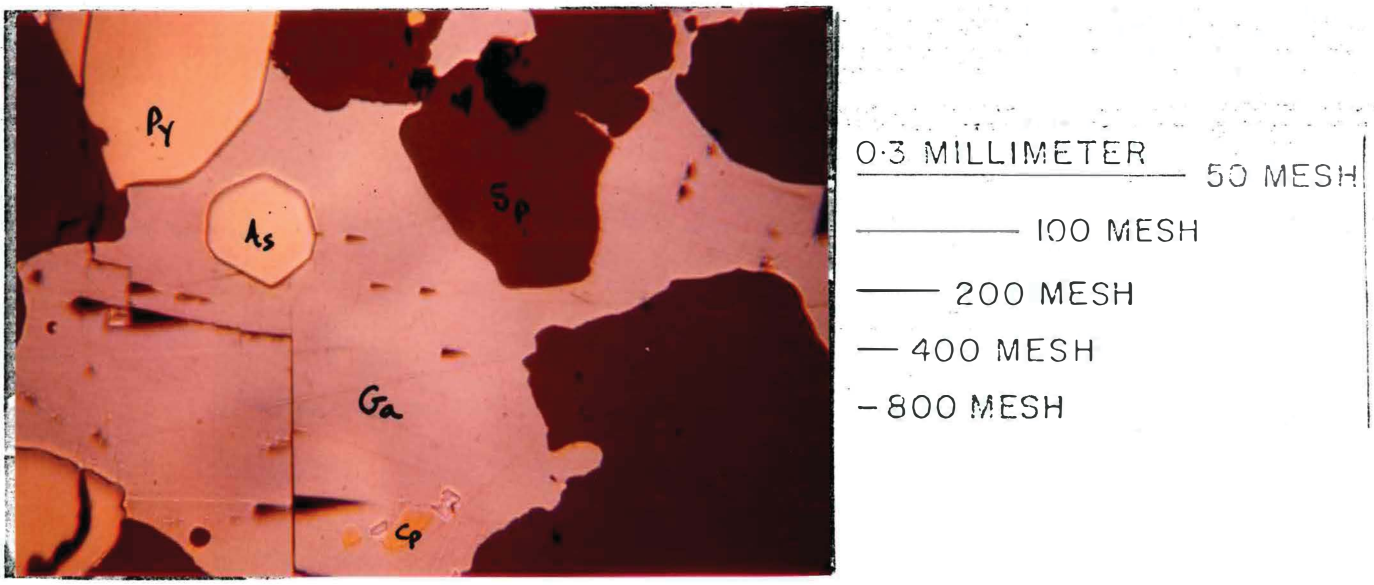


Figure 15 - Coarse Massive Sulphide Ore

This is a metallurgist's dream ore; unfortunately, it is not very common at Grum.

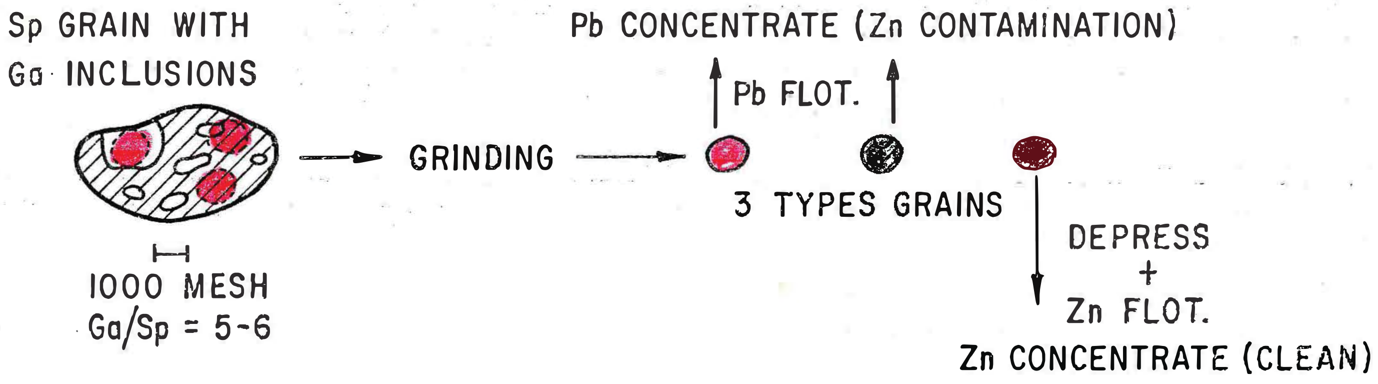
The writer has devised a six-fold classification of the galena-in-sphalerite (Ga/Sp) middlings texture, as illustrated in Figures 16 - 21. The following is a breakdown of the quantities of each of the six Ga/Sp classes of ore at 88 sites in the orebody.

Ga/Sp Rating for 88 Sites in the Grum Orebody

Ga/Sp Rating =	1	2	3	4	5	6
No. of Sites =	22	21	27	9	8	1
Percentage =	25	24	31	10	9	1

Metallurgical Response. A good indication of the metallurgical response of the various Ga/Sp classes of ore has been obtained from the study of certain metallurgical test products, and from the results of the various tests done by K.V. Konigsmann and K. Stowe of Mattagami on several samples of "B"-type ores and on the variety of ore-types collected by the writer in November, 1976.[1,2]

As illustrated below, and also in Figures 38 - 47, galena-



Pb Recoveries are good but Pb concentrates are contaminated
Zn Recoveries are low but Zn concentrates are clean

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[1] "Flotation Process for Ores from the Grum Deposit". Memo #4. K.V. Konigsmann, Mattagami Lake Mines Ltd. Dec. 30, 1976.

[2] "Vangorda-Grum", Progress Report #4. K. Stowe, Mattagami Lake Mines Ltd., Dec. 15, 1976.

PHOTOMICROGRAPHS OF Ga/Sp MIDDLINGS CLASSES 1-3

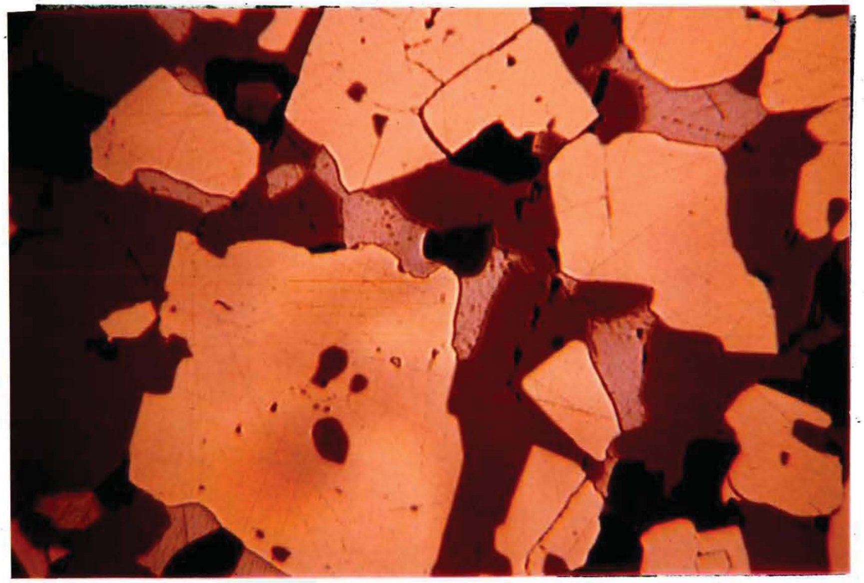


Figure 16 - Ga/Sp=1

Note clean separation of galena and sphalerite and absence of minus 1000 mesh galena.

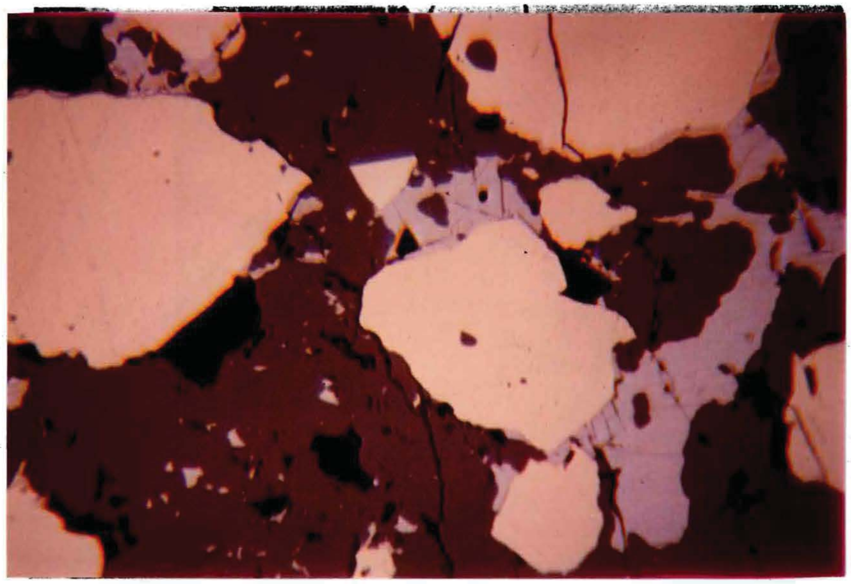
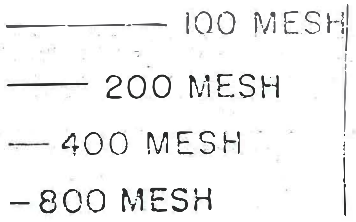


Figure 17 - Ga/Sp=2

Note minor amounts of minus 1000 mesh galena; some fine galena rims on pyrite.



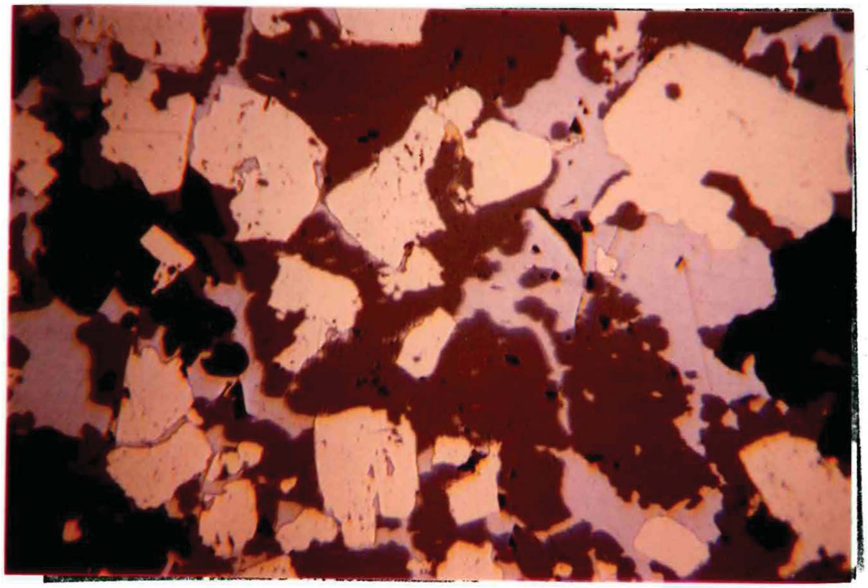


Figure 18 - Ga/Sp=3

Note moderate amounts of minus 1000 mesh galena in sphalerite, and increasingly intimate intergrowth of coarser galena with sphalerite.

PHOTOMICROGRAPHS OF Ga/Sp MIDDLINGS CLASSES 4-6

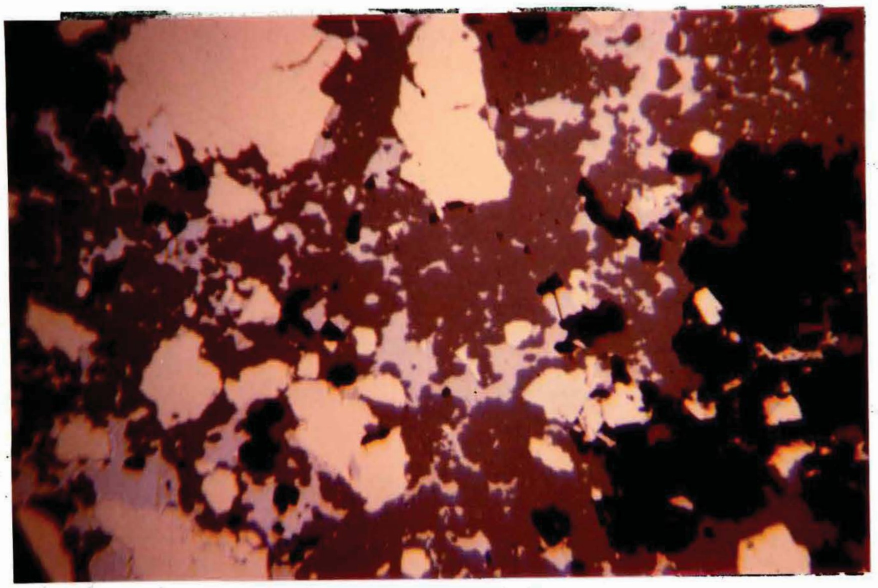


Figure 19 - Ga/Sp=4

Note moderately abundant minus 1000 mesh galena in sphalerite, and intimate intergrowth of coarser galena with sphalerite

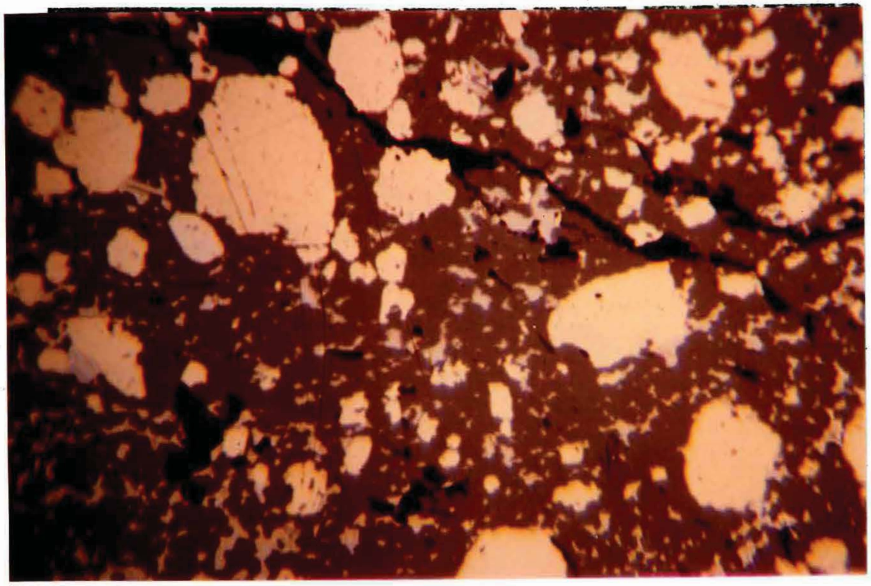


Figure 20 - Ga/Sp=5

Note very abundant minus 1000 mesh galena in sphalerite.

——— 100 MESH
—— 200 MESH
— 400 MESH
- 800 MESH

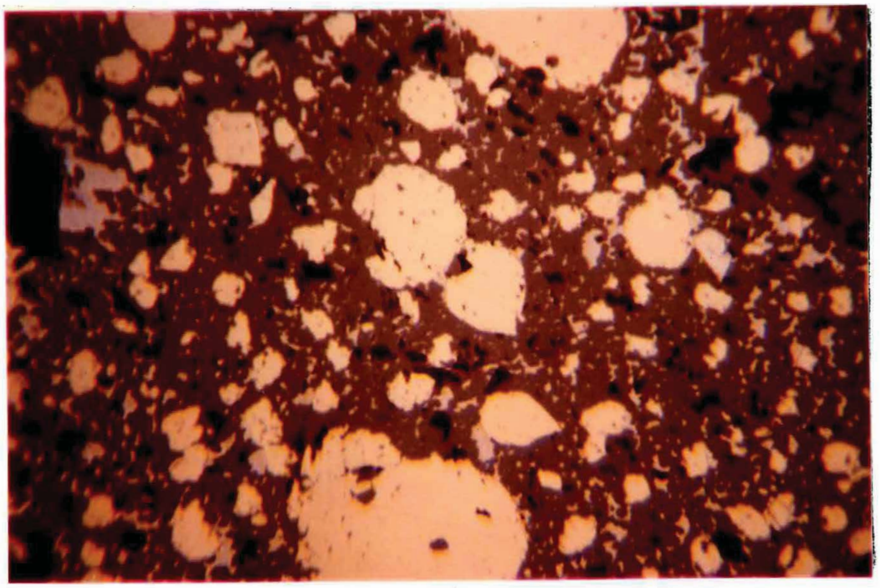


Figure 21 - Ga/Sp=6

Note that most galena is minus 1500 mesh (-10 U). Class 6 has been found only at metallurgical Site "B".

in-sphalerite middlings textures are the main cause of sphalerite contamination of lead concentrates. Figure 22 illustrates graphically the estimated Zn contamination in lead concentrates produced from the various Ga/Sp classes of ores.

Grain sizes in test products range from 250 mesh to less than 3000 mesh, with average grains about 1000 mesh. It is obvious that ores rating Ga/Sp=5-6 will produce more Ga/Sp middlings than the ores rating Ga/Sp=1-2. This is partly due to the very great contact surface area between galena and sphalerite in the 5-6 ores as compared to the 1-2 ores. In ores for which Ga/Sp=5-6, a very large proportion of the galena inclusions are minus 1500 mesh (10 microns); after grinding, many grains consist of small attachments of galena on larger sphalerite grains. This occurs partly because of the very fine grain size of galena but also because galena is soft and has very good cubic cleavage; small pieces galena tend to spall off during grinding, leaving only small attachments on the sphalerite. Because galena is floated first and is a highly floatable mineral, Ga/Sp middlings grains in which only a very small proportion of the surface area is galena, will float to the lead concentrate (Figures 38-43).

Because they contain a large proportion of galena grains in the minus 1500 mesh (-10 micron) size range, "B" ores must be very finely ground. In addition to the high grinding costs, much of this fine galena is slimed and therefore lost to the tailings[1].

Origin and Extent. Ore textures in which Ga/Sp = 4-5 appear to be common only in the uppermost (stratigraphic) part of

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[1] - according to K.V. Konigsmann, best recoveries occur for grains in the 40-10 micron size range (400-1500 mesh). Grains smaller than 10 microns tend to slime.

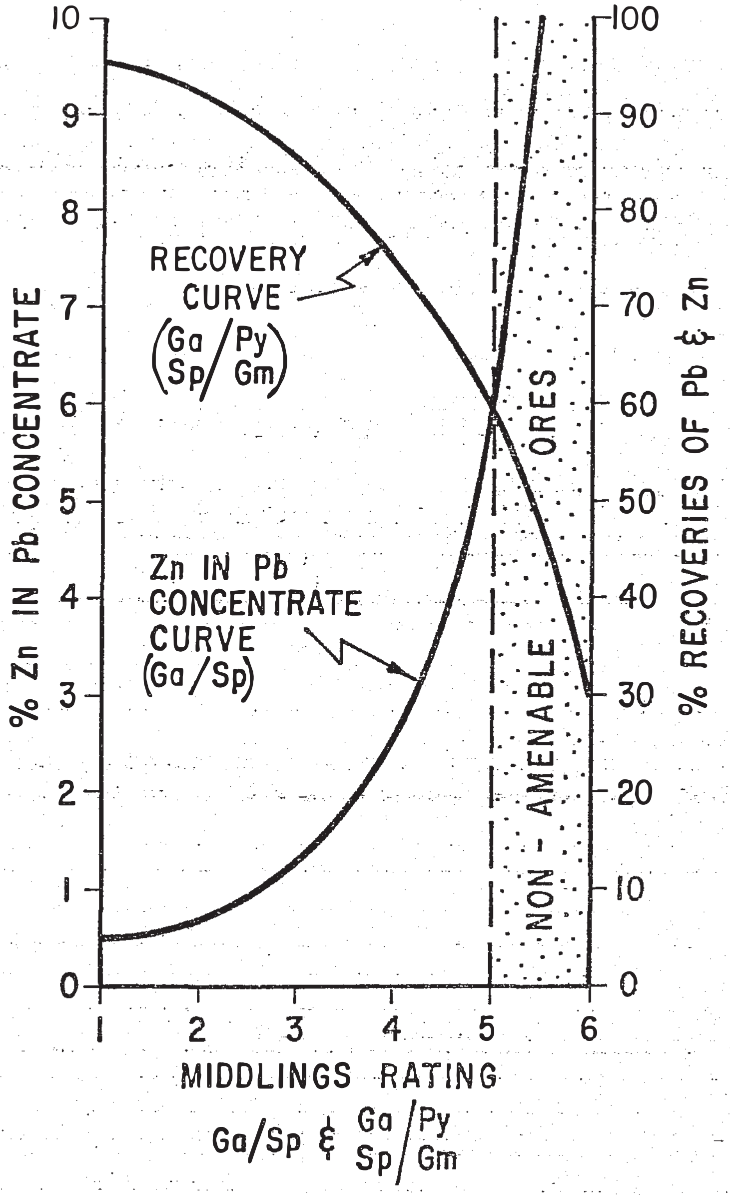


Figure 22 - Graphic Illustration of the Middlings Problems of the Grum Orebody

The curves indicate the very approximate, estimated relationships between Ga/Sp middlings and % Zn in Pb concentrates, and between $\frac{Ga}{Sp}/\frac{Py}{Gm}$ middlings and recoveries, based on microscopic study of polished sections from 88 sites throughout the orebody. The dashed vertical line at rating 5 is the writer's estimated dividing line between metallurgically-amenable and non-amenable ores, but this dividing line may actually be between ratings 5 and 6. The results of this study indicate that ores rating 5 and 6 constitute about 10% of the orebody --- ores in which Ga/Sp=6 have been found only at site "B", and ores rating Ga/Sp=5 occur at 9% of the 88 sites; ores with $\frac{Ga}{Sp}$/Py=5-6 occur at 8% of the sites, and ores with $\frac{Ga}{Sp}$/Gm=5-6 occur at 12% of the sites (mainly in "P" ores).

The term "non-amenable" is used here in a relative sense to indicate very fine, "B" type ores, which yield poor lead concentrates and give poor recoveries. The writer has observed Bathurst ores under the microscope and estimates that the bulk of these ores have $\frac{Ga}{Sp}$/Py=5-6 (see Figure 24) which would put them into the non-amenable class.

the orebody, that is, in the top portions of the massive sulphide layers. In stratigraphically-lower ores, including the quartz-sericite-chlorite "p" ores, the crystallization of galena and sphalerite into relatively coarse pure grains was common. It is suggested here that during the submarine deposition of the orebody, the uppermost parts of the orebody had little time to crystallize before submarine fumarolic action ceased and the orezone cooled down. By this theory, the top 1-2 meters of the orebody was, in effect, chilled, relative to deeper parts, and the "unmixing" of galena from sphalerite in the top ores was less complete than in deeper, more slowly cooled ores.

Ores with Ga/Sp ratings of 4-5 are not uncommon --- they occur at 19% of the 88 sample sites studied. However, ores with Ga/Sp = 6 have been found only at site "B" (see below). The writer believes that during the compressional faulting which occurred at site "B", galena and sphalerite in the top two meters of the orebody, (which probably had a Ga/Sp rating of 4-5) were recrystallized under pressure. During this recrystallization, galena was dispersed even more finely throughout sphalerite to yield an extreme Ga/Sp middlings problem.

?

Galena and Sphalerite-With-Pyrite Middlings Texture $\left(\frac{Ga}{Sp}/Py\right)$

Occurrence and Classification. There are three types of $\frac{Ga}{Sp}/Py$ middlings textures at Grum: (1) galena and sphalerite occur as inclusions in individual pyrite crystals (see Figure 7 - minor Ga/Py, and Figures 16, 17, 18 - minor Sp/Py). This texture is not metallurgically important at Grum because it is rarely well-developed

--- most pyrite at Grum is relatively free of inclusions (Figures 5-26). (2) galena and sphalerite fill spaces between closely-packed pyrite crystals in high-pyrite bands (Figures 23, 24, 25). This texture is relatively common and is the main source of $^{Ga}_{Sp}/Py$ middlings in concentrates and tailings. Obviously, it is restricted to the massive sulphide portions of the orebody. (3) fine pyrite occurs within galena and sphalerite (Figures 25, 26). This texture is not common but does contribute minor quantities of galena-pyrite and sphalerite-pyrite middlings.

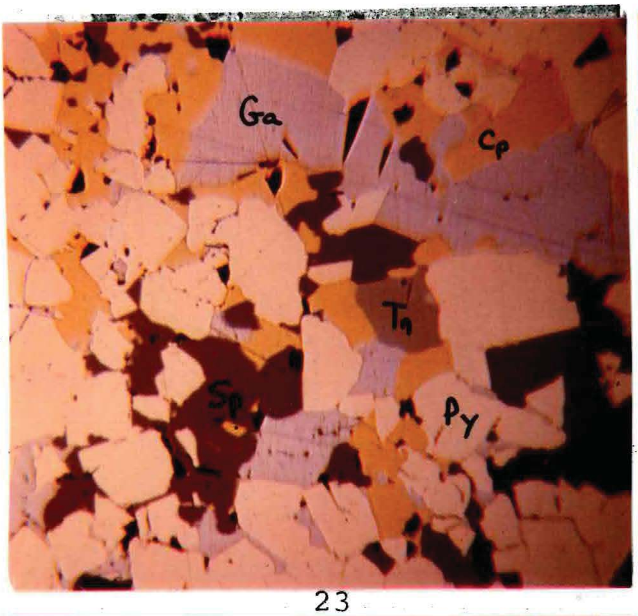
The $^{Ga}_{Sp}/Py$ textures have been rated 1 to 6, negligible to extreme, by the writer (Figures 23-26). Following is a breakdown of the each of the six $^{Ga}_{Sp}/Py$ classes of ore at 88 sites in the orebody.

$^{Ga}_{Sp}/Py$ Rating of 88 Sites in the Grum Orebody

$^{Ga}_{Sp}/Py$ Rating	=	1	2	3	4	5	6
No. of Sites	=	11	29	30	11	6	1
Percentage	=	12.5	33	34	12.5	7	1

Metallurgical Response. The above $^{Ga}_{Sp}/Py$ textures result in moderate amounts of pyrite middlings. Usually, large pyrite fragments have smaller attached grains and rims of sphalerite and/or galena. As shown graphically in Figure 22, ores with $^{Ga}_{Sp}/Py = 5-6$ have low recoveries because considerable galena, but particularly sphalerite are carried off to the tailings on the larger pyrite fragments (Figures 46, 47).

PHOTOMICROGRAPHS OF $\frac{\mathrm{Ga}}{\mathrm{Sp}}$/Py MIDDLINGS TEXTURES



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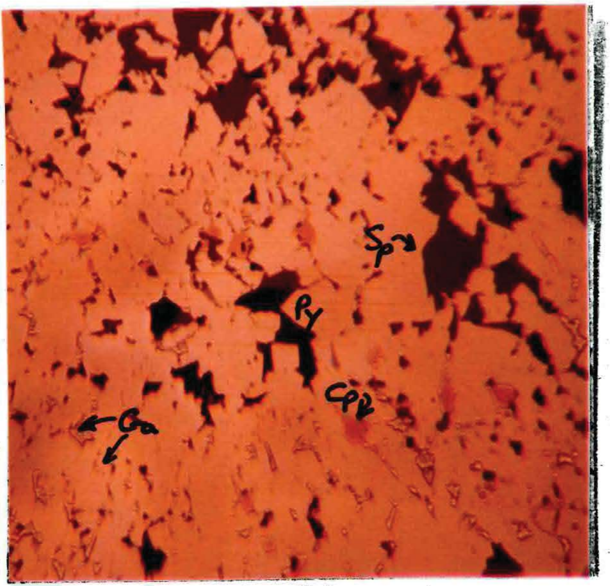

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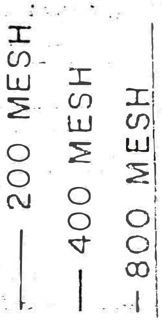

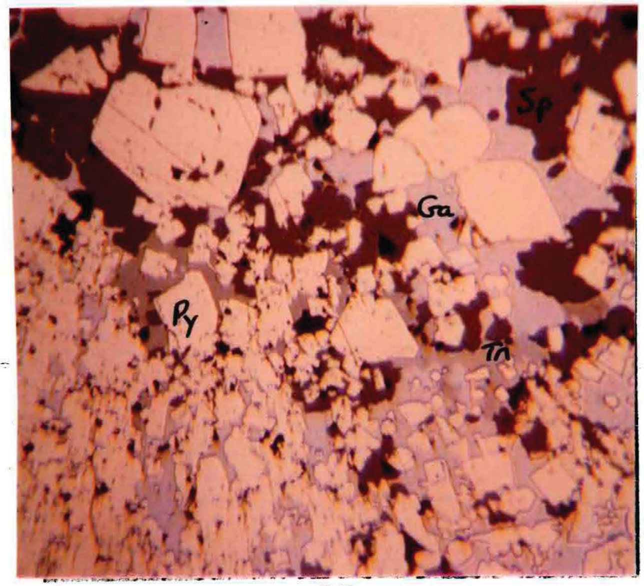

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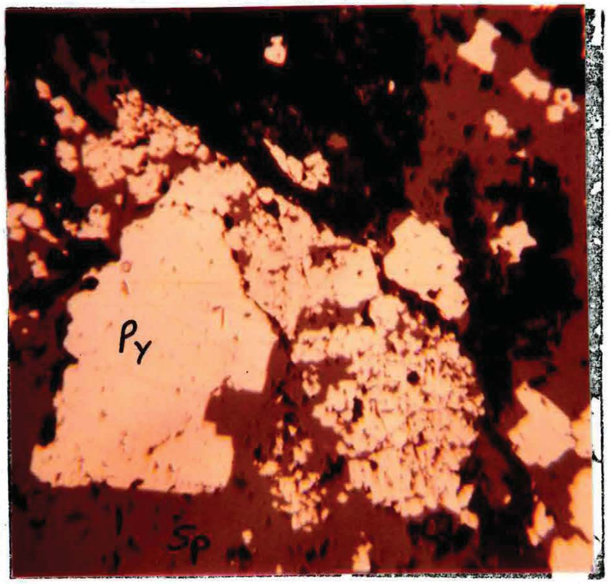

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Figure 23 - $\frac{\mathrm{Ga}}{\mathrm{Sp}}$/Py=2.

Galena and sphalerite and chalcopyrite and tennantite are interstitial to pyrite and are relatively coarse.

Figure 24 - $\frac{\mathrm{Ga}}{\mathrm{Sp}}$/Py=5.

This type of texture is the main cause of the metallurgical problems at Brunswick but fortunately is not nearly as common at Grum. It results in abundant Ga/Py and Sp/Py middlings.

Figure 25 - $\frac{\mathrm{Ga}}{\mathrm{Sp}}$/Py=2-3 (Top) and Ga/Py=4-5 (Bottom).

Two adjacent bands having different textural ratings. Pyrite-galena middlings would be produced from the bottom band, partly due to the fineness of pyrite.

Figure 26 - Sp/Py=3-4.

Most pyrite is coarse and clean, but finer clusters would cause some Sp/Py middlings to form.

Ores with $\frac{Ga}{Sp}/Py = 5\text{-}6$ yield low grade lead concentrates because a large number of galena-pyrite middlings grains are pulled up during lead flotation. Zinc concentrates are less affected, partly because a large proportion of the middlings have already reported to the lead concentrates. Figures 38-47 illustrate the occurrence of $\frac{Ga}{Sp}/Py$ middlings in flotation products.

Ores with $\frac{Ga}{Sp}/Py = 5\text{-}6$ constitute only 8% of the 88 sites studied(above). This type of middlings problem is much less serious at Grum that at some other, producing mines (i.e. - Bathurst camp mines).

Galena and Sphalerite-In-Gangue Middlings Texture($\frac{Ga}{Sp}/Gm$).

Occurrence and Classification. Gangue minerals at Grum, excepting pyrite (considered separately, above), consist largely of quartz, sericite, chlorite, and locally barite. In non-massive ores, fine galena and sphalerite may occur: (1) as fine, randomly distributed inclusions in quartz; (2) as blebs and strings along gangue mineral grain boundaries, or (3) in blebs along cleavage planes in sericite and chlorite.

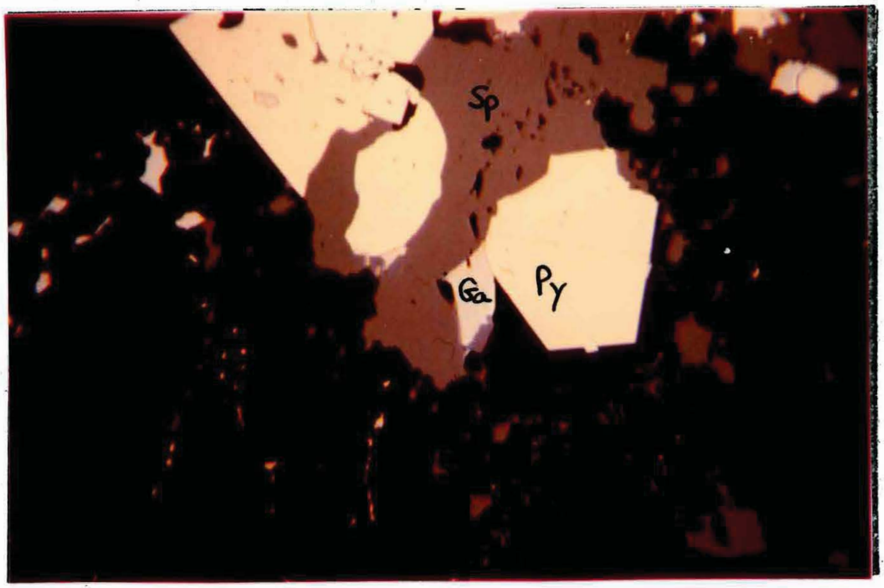
Most types of massive sulphide ores have only minor quartz, sericite, or chlorite; in Mb, baritic ore, barite is invariably free of inclusions (Figure 9). Thus $\frac{Ga}{Sp}/Gm$ middlings textures in most massive sulphide ores are weak to negligible. However, in quartz-rich massive sulphides (M_Q - Figure 6) quartz-galena-sphalerite middlings textures range from weak to moderate; in the quartz-sericite-chlorite ores (= P ores) $\frac{Ga}{Sp}/Gm$ middlings textures range from weak to very strong.

The writer has classified the $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm middlings textures observed at the 88 Grum sites in a manner similar to that for Ga/Sp or $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Py and this classification is presented below. The classification of $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm middlings textures should be taken as less definite than for the other types of middlings textures because: (1) the only ores which have been tested metallurgically to date, other than the bench-scale tests on the samples collected during this study, are massive sulphides low in quartz, sericite, and chlorite --- no test products of "P" ores have been available for study; (2) many samples possess a mixture of both coarse and fine galena and sphalerite in groundmass; in effect, many are a mixture of $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm = 1-2 and $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm = 4-5. It is difficult to estimate the average rating for such samples. The ratings were made without taking into consideration the fact that the coarser grains are much more important in that they contain most of the Pb and Zn --- thus a sample in which 50% of the area had $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm = 1 and 50% had $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm = 5 was rated at 3 but this rating could be considered high if compared to the ratings for the more uniform Ga/Sp and $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Py middlings textures; (3) the writer suspects that the gangue minerals tend to break apart easily along their contacts and cleavages during grinding, thereby releasing even very fine interstitial galena and sphalerite. If so, only the extremely fine inclusions could present problems, but these contain only a very minor proportion of the Pb and Zn. Following is a breakdown of the $\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm middlings textures at the 88 sample sites.

$\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm Rating of 88 Sites in the Grum Orebody

$\genfrac{}{}{0pt}{}{\text{Ga}}{\text{Sp}}$/Gm Rating	=	1	2	3	4	5	6
No. of Sites	=	12	18	32	15	10	1
Percentage	=	14	21	36	17	11	1

PHOTOMICROGRAPHS ILLUSTRATING $\genfrac{}{}{0pt}{}{Ga}{Sp}/Gm$ MIDDLINGS TEXTURES



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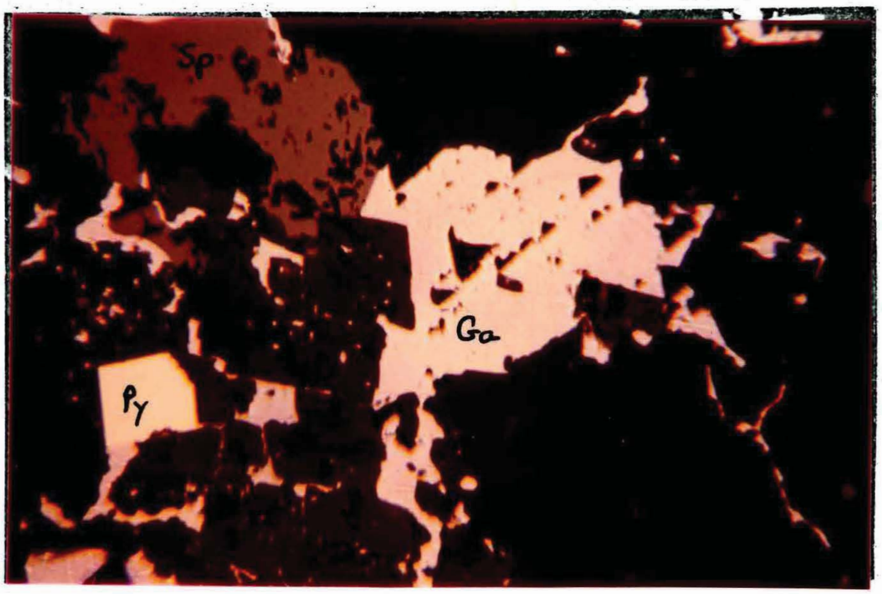

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Figure 27 - $\genfrac{}{}{0pt}{}{Ga}{Sp}/Gm$ = 4 in P Ore

Fine galena and sphalerite are common in gangue; nevertheless, coarser grains actually contain most of the Pb and Zn.

Figure 28 - Ga/Gm=4 in P Ore

As with Figure 27, most of the Pb is actually contained in coarse grains.

Metallurgical Response. As shown in Figure 22, $^{Ga}_{Sp}/Gm$ textures of 5-6 probably result in relatively low recoveries since galena-gangue and sphalerite-gangue middlings would be lost to the tailings (Figure 47). The seriousness of this problem is not well-known because little metallurgical testing has been done on P or M_Q ores. However, the problem is not believed by the writer to be great since the bulk of the galena and sphalerite in P and M_Q ores is relatively coarse, and the finer grains tend to be interstitial and weakly-bonded. Limited metallurgical testwork done on quartz-rich massive sulphide ore B4 and on P ores collected by the writer tend to support this belief (see APPENDIX).

Oxidation

Occurrence and Extent. Zones of strongly oxidized (limonitized) massive sulphide (Figure 29) are present at Grum. However, from the inspection of core from 60 drill holes and of the underground workings, the writer concludes that most of these are small lenses that probably constitute less than 5% of the massive sulphide portion of orebody. They occur almost exclusively in the upper (elevation) and particularly the upper eastern parts. The only known large zone of oxidized ore is the block of fault-bounded massive ore on section 70W which includes metallurgical site "F" (Figures 3, 29). However, only certain granulated bands are strongly oxidized. Significant oxidation has not been observed in any of the P ores that underly the massive ores.

It should be noted that very minor amounts of oxidation (the odd limonite-coated joint) occur throughout most of the orebody but these do not appear to cause metallurgical problems.

In all of the several hundred meters of ore intersected by the underground workings, only two sites, "B" and "F" (Figure 31) display strongly-oxidized rocks and this strong oxidation is restricted to only certain highly granulated or strongly-fractured massive sulphide horizons adjacent to strong faults (Figures 3, 29, 32).

In some deposits, strong oxidation shows a close relationship to pyrrhotite content, but at Grum such a correlation is not evident. Abundant pyrrhotite has been found at only 4 of 88 sites at Grum; only one of these 4 sites, which is near the highly oxidized site "F", has significant oxidation. Further, no pyrrhotite has been observed at either site "F" or site "B".

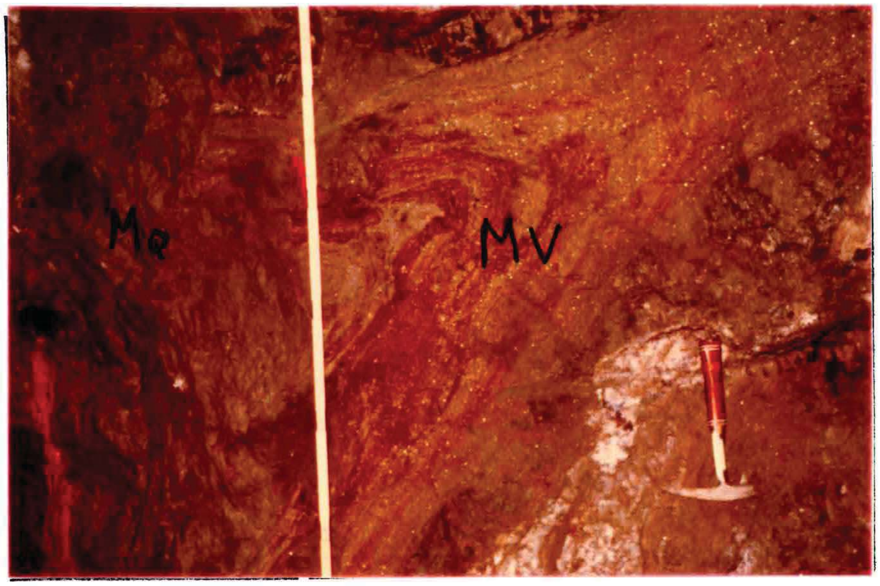


Figure 29 - Strongly Oxidized, Folded and Granulated Massive Sulphide (MV) at Site "F".

Massive sulphides at "F" occur in a large block of ore that is between 2 major gouge-filled fault zones (see Figure 3). Tight folding, and movement on these faults, have caused granulation of less competent horizons (MV above), rendering them permeable to oxidizing groundwaters. More competent quartz-rich massive sulphide band (M_Q above) was not granulated and is therefore not strongly oxidized. Clayey (kaolinite) gouge zones occur in the massive sulphides next to the hammer.

There are two main types of permeable ores at Grum and these are susceptible to oxidation. They are massive, vuggy (MV) ore and massive, crackled, high-pyrite ore (Mpy).

Ores Susceptible to Oxidation

Type I	Type II
Massive vuggy ore, MV. Relatively soft, high-grade, usually baritic bands, with moderate amounts of pyrite --- granulated during deformation. See Site "B" map = Figure 32, and Figures 29, 2, 4, 10.	Massive high-pyrite ore, Mpy. Relatively hard, brittle bands --- crackled during deformation. See Site "B" map = Figure 32, and Figures 4, 34.

It should be emphasized that only where there was access to oxidizing groundwaters were granulated (porous) MV and crackled (porous) Mpy oxidized (see Figure 30). Groundwaters gained access to these porous units from fault zones, mainly in the parts of the orebody closest to ground surface. The soft, high-grade baritic ore lenses (Mb) that occur near the stratigraphic top of the orebody were particularly susceptible to granulation (granulated Mb=MV) and subsequent oxidation.

As is the case with pyrrhotite (above), oxidation shows no relationship to the very minor marcasite contained in the Grum ores, and marcasite has not been found at sites "F" or "B".

Figure 30 - Granulated, Unoxidized Porous Massive Sulphides (MV), Probably Baritic

Though permeable, most MV bands were not oxidized because they were not transected by faults carrying oxidizing groundwaters.

Surficial oxidation of already-oxidized high-pyrite ore (i.e. metallurgical sample B_3 - below) from site "B" is known to occur if the ores are exposed for several weeks (Figure 34). This type of oxidation has not been observed in samples from other localities at Grum.

Metallurgical Response. According to K.V. Konigsmann, "oxidation" is a catch-all term used by many metallurgists to explain a great variety of metallurgical problems some of which are totally unrelated to oxidation of the ores. Nevertheless, oxidation can be a very serious problem and according to Konigsmann, a small amount of oxidized ore can spoil an entire batch.

Tests carried out on "B" and "F" ores show that oxidation has a very deleterious effect on metal recoveries. From the study of test products from "B" samples (Figure 41-47), it is apparent that oxidation magnifies the middlings problems; more $\frac{Ga}{Sp}$/Py and $\frac{Ga}{Sp}$/Gm middlings than normal are lost to the tailings, probably because galena, and particularly sphalerite, are desensitized if oxide coatings are extensive. On the other hand, some oxide-coated pyrite and sphalerite fragments, with or without galena inclusions, seem to be activated during lead flotation (Figures 41-43).

"B" samples have both extreme oxidation and an extreme Ga/Sp middlings problem, whereas sample 1, which is from site "F" has extreme oxidation, but no serious middlings problem (see Table III). The high metal losses, particularly Zn, to the tailings in sample 1 (Table III) show that oxidation is a major problem by itself. Perhaps due to its Fe content, sphalerite appears to be more susceptible to thick coating by oxide than galena. Therefore, sample 1 which has been affected by oxidation only, shows less loss of Pb to the tailings than the "B" samples 3, 5 and 7 which may owe some of their higher Pb losses[1] to their extreme Ga/Sp middlings problem.

---

[1] Konigsmann describes Pb in the "B"-type samples as being "reluctant to float". In Bathurst ores this "reluctance to float" is thought to be due to the coating of galena by $PbSO_4$ and $CuSO_4$ produced during the very fine grinding of these extremely fine but unoxidized ores. Sulphates may be present in the oxidized Grum "B" ores, and additional sulphates may be produced during the very fine grinding required for these ores, although, oxide coatings have not been observed on galena of the test products (Figures 38-47). The writer believes that the reluctance of "B"-type galena to float may be explained by the fact that due to the Ga/Sp=6 middlings problem, a large % of galena grains have even larger attachments of sphalerite and are therefore held down during lead flotation; thin oxide coatings on galena, not seen in test products because they have been washed off during sample preparation, may further promote this process by desensitizing the galena.

Sliming

Sliming is a major cause of galena losses to tailings in "B"-type Grum ores. Because of their extreme Ga/Sp=6 middlings textures, "B"-type ores must be very finely ground. This creates abnormally high levels of minus 10 micron grains which, due to their very great surface area, reduce the effectiveness of reagents. Galena is particularly susceptible to sliming because it is soft and breaks easily on its cubic cleavage planes. Some slimed sphalerite is lost to tailings but most Zn losses are in middlings.

Slimed galena, as well as lesser amounts of slimed sphalerite and pyrite, are shown in Figures 43, 46, 47.

Serious sliming is innevitable in ores such as those at "B" which have Ga/Sp=5-6, but such ores are very minor at Grum.

Graphite

Graphite can cause activation of sphalerite. However, only very minor amounts of graphite have been seen in the Grum ores and test products studied by the writer. The graphite observed was very fine discrete grains; coatings on galena and spalerite were not seen, but may have been washed off in sample preparation.

Graphite does not appear to be a problem within the massive sulphide ores. It could, however, present problems locally due to hanging wall dilution or dilution from graphitic phyllite lenses within the quartz-sericite-chlorite ores (P ores).

CONCLUSIONS

Following are the main conclusions of this investigation:

(1) the main metallurgical problems encountered with Grum ores are oxidation and galena-sphalerite middlings. Both probably occur in serious proportions in only a very small portion (< 5%) of the orebody (oxidation causes metal losses to the tailings; galena-sphalerite middlings result in zinc contamination of lead concentrates).

(2) most of the Grum ores that were tested metallurgically up until November, 1976 were not representative of the orebody --- they possessed the two metallurgical problems to extreme degrees.

(3) grain size of the Grum orebody, though relatively fine, is much coarser than ores known to be metallurgically difficult, such as those of the Bathurst area.

(4) it should be possible to obtain acceptable metallurgical results for greater than 90% of the Grum orebody.

RECOMMENDATIONS

The following recommendations, made orally in late January, have already been partly followed up:

(1) a request was made for a large number of additional specimens that could be studied under the microscope in order to positively and accurately delimit and classify the various metallurgical types of ores. As a follow-up to this recommendation, approximately 750 drill core specimens from throughout the orebody were collected for the writer in early February by J. Paxton and A.Y. Po. These have been received. Work will be completed on them by June 30, 1977.

(2) it was recommended that several additional bulk metallurgical samples, representative of typical Grum ores, should be collected for definitive metallurgical testing. This also has been followed up; samples from underground sites "F"(2), "D", "H", and "G" were collected by J. Paxton in early February. Samples from sites "A" and "C" were already available and will also undergo testing.

(3) a request was made that all drill core and/or drill logs be reexamined with the object of delimiting all pockets of oxidation. Since these pockets are most common in the parts of the orebody closest to ground surface, they could have negative effects on the metallurgy of the initial ore mined in an open-pit. This has apparently been followed up by J. Paxton.

APPENDIX

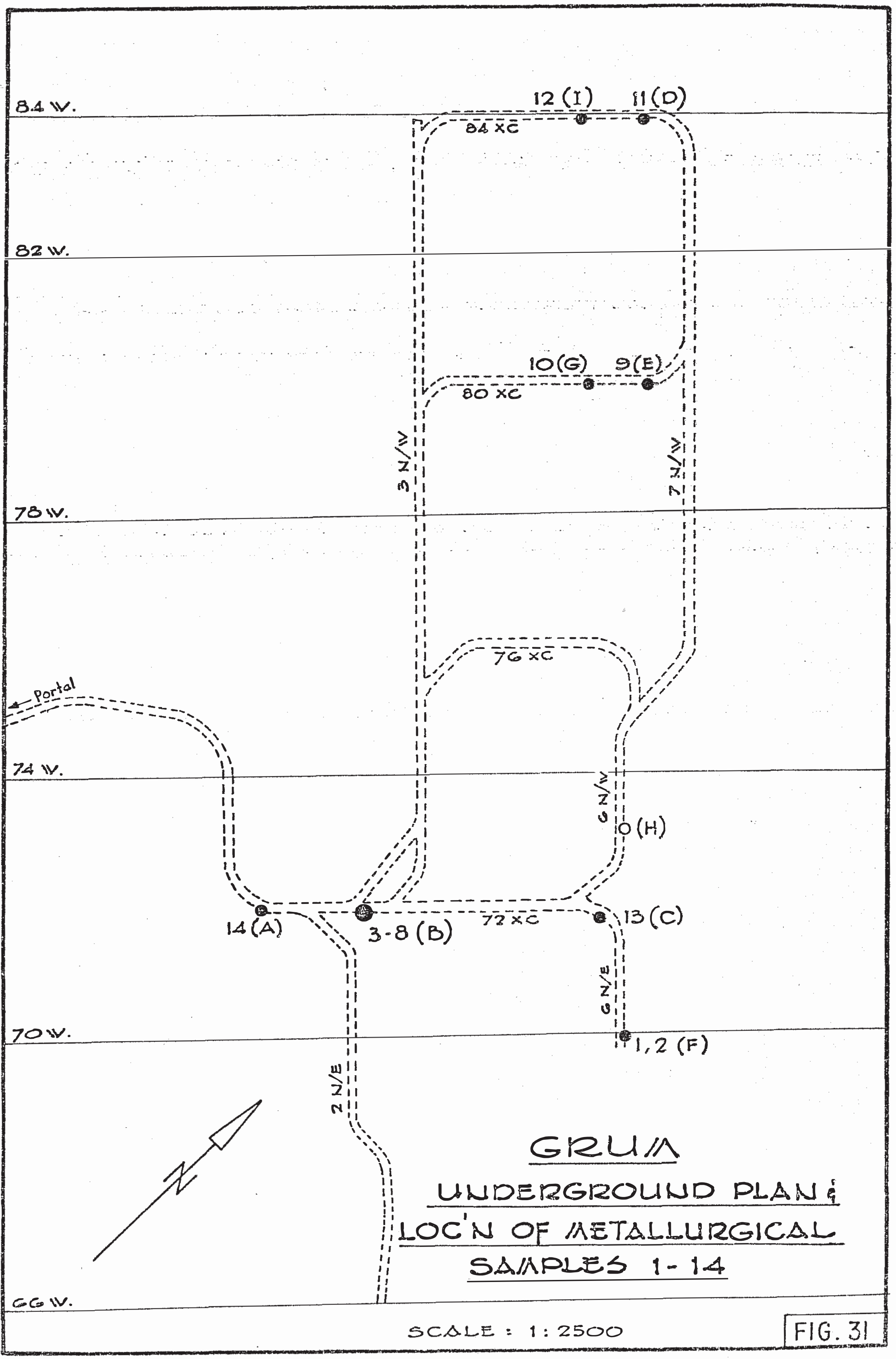
Description of Site "B" and "B"-Type Samples

Geology and Ore-Types of Site "B". The first major, readily accessible ore intersection encountered during underground drifting at Grum was at site "B" (Figure 31). A thorough knowledge of the geology and ore-types of site "B" is imperative because it was the source of most material used for metallurgical testing done to date. Site "B" is one of 8 underground sites from which metallurgical samples were collected by the writer (Figure 31).

The geology of site "B", as it appeared in early November, 1976 is shown in Figure 32. Because a large number of samples have been slashed from site "B", mainly from the ore bands between the two faults, there is a 3-4 meter-deep cut between the phyllite and the M_Q+MB band.

Site "B" is at the stratigraphic top of the Grum orebody (Figure 32b). Most of the exposure is between two segments of a major compressional fault which follows the contact between the massive sulphides and the overlying graphitic phyllites (Figure 32b). These faults, shown in detail in Figure 32a, are steeply-dipping and are gouge-filled (=Kaolinite --- X-ray identification).

Several types of ore occur at site "B" and the proportions of each exposed on the face at any given time varied as the cut was continually deepened due to the blasting off of numerous bulk samples. The central, highly-oxidized MV band apparently narrowed into the face so that it contributed the major proportion to earlier metallurgical samples (J. Paxton, personal communication). Later samples had larger proportions of the less strongly oxidized, hard MB+M band;



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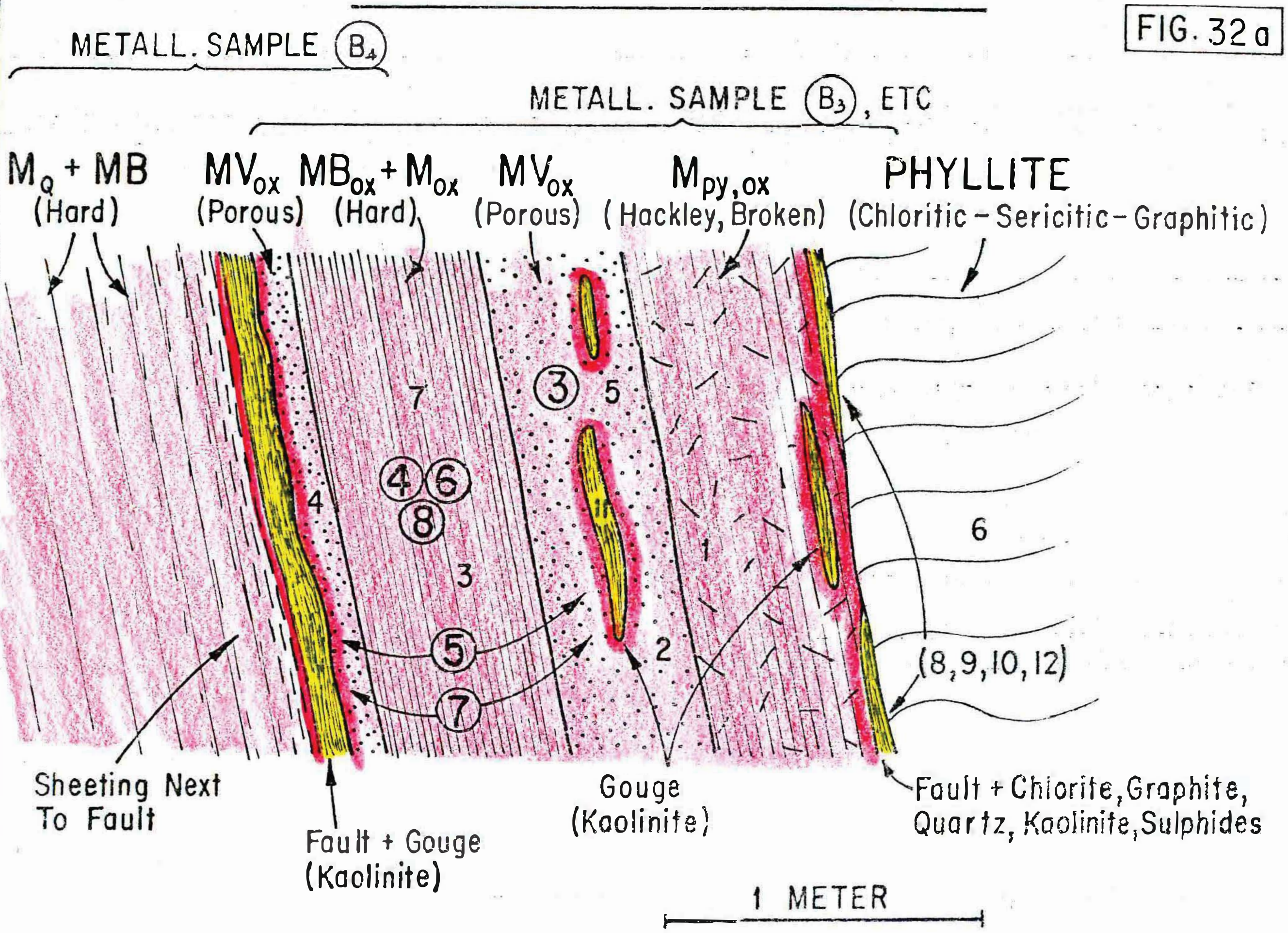
UNDERGROUND PLAN & LOC'N OF METALLURGICAL SAMPLES 1 - 14

SCALE : 1: 2500

FIG. 31

SKETCH-MAP OF SITE "B"

FIG. 32a

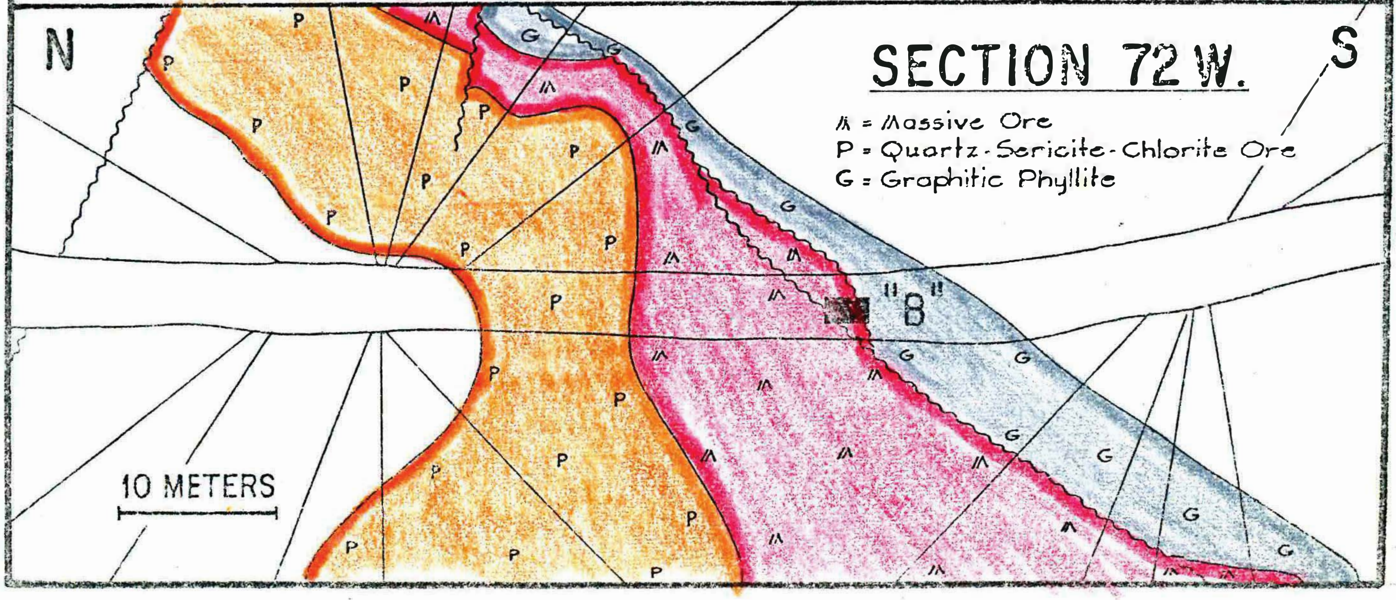


③-⑧ = Metallurgical Samples 1 – 12 = Representative Specimens

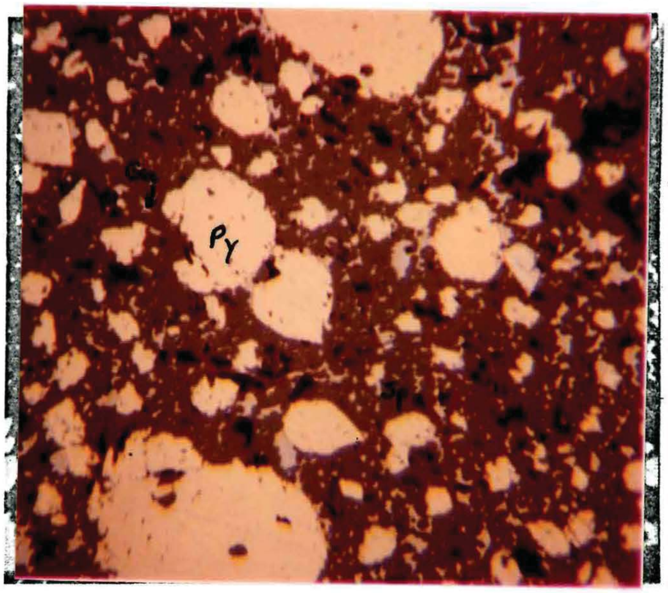
M = Massive Sulphide; MB = Banded M; MV = Vuggy M; M_Q = Siliceous M

STRATIGRAPHIC POSITION OF SITE "B"

FIG. 32b



PHOTOMICROGRAPHS OF ORES FROM SITE "B" (see Figure 32)



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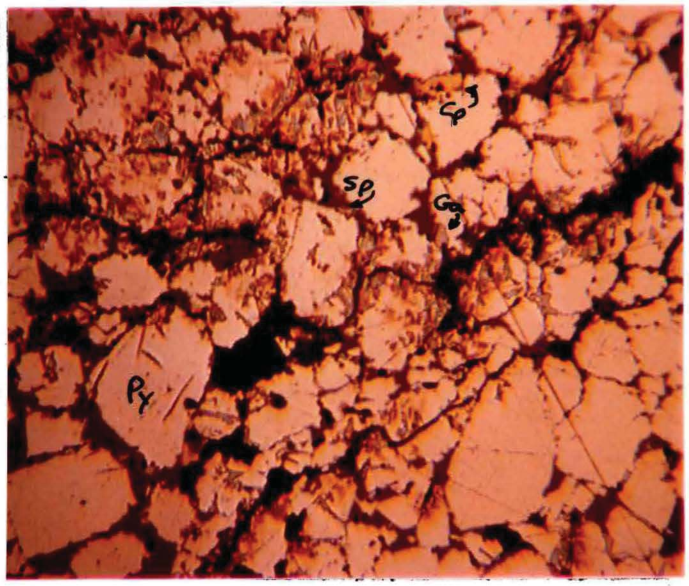

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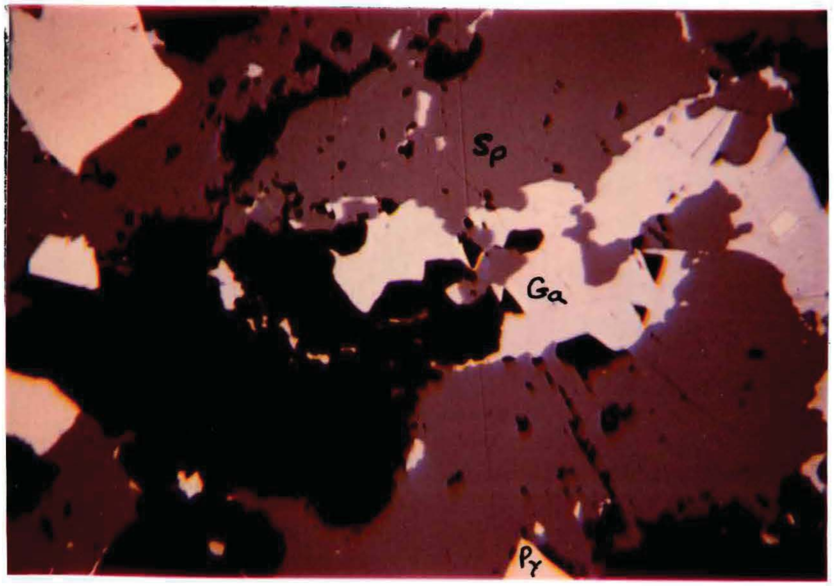

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100 MESH
200 MESH
400 MESH
800 MESH

Figure 33 - MV Ore With Ga/Sp=6 and Strong Oxidation.

Black spots are limonitic pits. MV with Ga/Sp=5-6 was major component of all metallurgical samples from site "B" excepting B_4.

Figure 34 - Mpy Ore From Hackley Band Abutting Phyllites.

Surficial oxides(?) spreading outward from black limonitic cracks have developed since the polished section was made (2 months). $\frac{Ga}{Sp}/Py=4-5$. This oxidized Mpy was a major component of metallurgical sample B_3.

Figure 35 - M_Q Ore Typical of Hard Ores on N Side of Site "B"

Negligible oxidation --- dark patches are quartz. Ga/Sp=2. M_Q was a major component of metallurgical sample B_4.

the second-last sample, B_3, was taken mainly from the south side of the site and was therefore characterized by a large proportion of hackley, oxidized Mpy. Sample B_4 was derived from the north side of the exposure and had a large proportion of unoxidized, hard, quartz-rich ore.

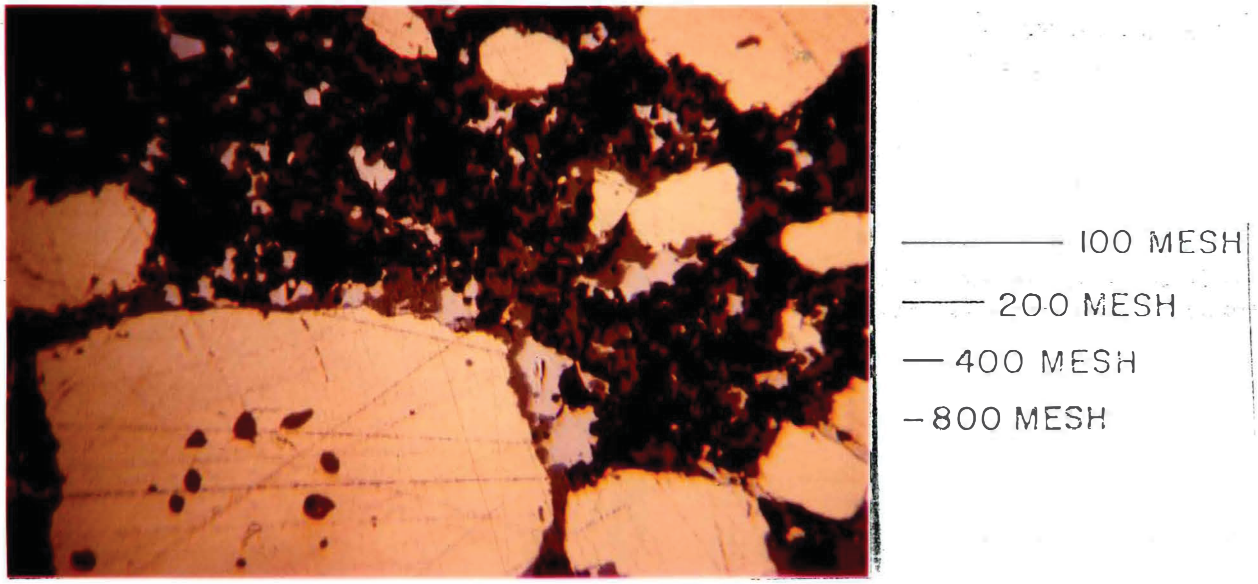

Figure 36 - Granulated MV.

From the narrow band of MV adjacent to the N fault at site "B" (Figure 32). Note rolled-out pyrite with galena-sphalerite rims. Ga/Sp=4; $\frac{\mathrm{Ga}}{\mathrm{Sp}}$/Gm=5. Many dark spots are limonitic pits. The rock is actually "mylonitized" massive sulphide.

As indicated above, the several types of ore-bands at site "B" show widely-varying degress of oxidation --- the harder M_Q, MB and M bands are less oxidized than the porous MV bands and permeable hackley Mpy band adjacent to the fault on the south. Adding to the complexity of site B is the fact that middlings types and ratings also vary widely among the various bands. The wide MV band is characterized by Ga/Sp=6 and the MB+M band by Ga/Sp=5, whereas the M_Q+MB band has Ga/Sp=3. In contrast, the Mpy band has a serious $\frac{\text{Ga}}{\text{Sp}}$/Py middlings problem plus some minor lenses of Ga/Sp=6. Following is a breakdown of the main characteristics of the metallurgical samples derived from site "B".

SAMPLE	MAIN ORE TYPE (Subordinate)	OXIDATION	Ga/Sp	$\frac{\text{Ga}}{\text{Sp}}$/Py	$\frac{\text{Ga}}{\text{Sp}}$/Gm	METAL-LURGICAL RESPONSE
Early "B"'s	MV(MB,M,Mpy)	Vy Strong	4-6	3(est)	2(est	Poor
B_3	Mpy(MV,G)	Vy Strong	4(3-6)	4	2	Poor
B_4	M_Q(MBpy, MV,M)	Mod-Minor	3(1-6)	4(1-5)	3(1-5)	Inter-mediate
3,5,7,	MV	Vy Strong	5.5 (4-6)	3	3	Poor
4,6,8,	MB+M	Moderate	5	2	3	Inter-mediate

Table II - Characteristics of the Various "B" Metallurgical Samples

Most "B" samples have both strong oxidation and serious middlings problems. Further, "B" is the only site at which Ga/Sp=6 ratings are known to occur. "B" samples must therefore be considered highly unrepresentative of the Grum orebody because a combination of these two major metallurgical problems has not been found at any other of the 88 orebody sites studied.

Sample B_4 has the least oxide and the least serious middlings problems of all the "B" samples but nevertheless is worse than most Grum ores. In extensive metallurgical tests, sample B_4 yielded the following results[1]:

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[1] report by K.V. Konigsmann referred to on p.15.

	Assays		Distribution	
	Pb	Zn	Pb	Zn
Pb Concentrate	45	8-10	75	
Zn Concentrate	2.5	52+		80
Zn Rougher Tails	1.0	1.5		
Head	4.7	9.3		

The above results approach acceptability despite the fact that B_4 contains about 10% highly oxidized MV, much of which has Ga/Sp = 6. The "average" Grum ore should behave much more favourably.

Description and Metallurgical Response of Metallurgical Samples 1-14 From Sites A-I

Table III gives the main characteristics of the metallurgical samples 1-14 collected by J. Paxton and the writer. These samples have each been subjected to a standard flotation test[1], some results of which are included in Table III. These tests are considered indicative but by no means final since there was no optimization of reagent combinations or fineness of grinding. The samples have been grouped according to their metallurgical response (poor, intermediate, acceptable) as indicated by K.V. Konigsmann[1].

Group	Percent[2]	Samples	Ore-Types & Source	Main Metallurgical Problems
Poor Gp.	3	1,3,5,7	MVox from "B" & "F"	Poor ores yield unacceptably low grade Pb rougher concentrates that are too high in pyrite and Zn; Zn recoveries are too low. Intermediate and Acceptable ores are correspondingly better.
Intermediate Gp.	7	4,6,8,14	hard "B" ores +Mpy±ox from "A"	
Acceptable Gp.	90	2,9,10, 11,12,13	MQ,P,M from C,D,E,F,G,I	

Close inspection of Table III and of other data presented in this report allow for the following deductions concerning the metallurgical response of Grum ores:

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[1] reports by K.V.Konigsmann and K. Stowe, referred to on p.15.

[2] very approximate, estimated percentage of the entire orebody for each group.

(1) acceptable metallurgical results have been obtained from ores which probably constitute > 95% of the Grum orebody --- i.e. - unoxidized samples of M, M_Q, and P from C, D, E, F, G, and I.

(2) poor metallurgical results have only been obtained from intensely oxidized vuggy massive sulphide ore (MV) from sites "B" (3,5,7) and "F" (1). Such ores probably constitute < 5% of the orebody. The "B" samples, 3, 5, 7, also have a uniquely extreme Ga/Sp middlings problem whereas the "F" sample, 1, does not. Perhaps with further work, results for sample 1 could be improved, and this should be one aim of tests done on the new bulk sample from "F" - i.e. - is extreme oxidation alone sufficient to render Grum ores extremely difficult metallurgically.

(3) samples yielding intermediate metallurgical results are the hard B samples (4, 6, 8) in which oxidation is not as intense as in 3,5,7, yet Ga/Sp=5, and sample 14 from site "A" which possesses mild oxidation combined with $\frac{\text{Ga}}{\text{Sp}}/\text{Py}=4$ middlings rating.

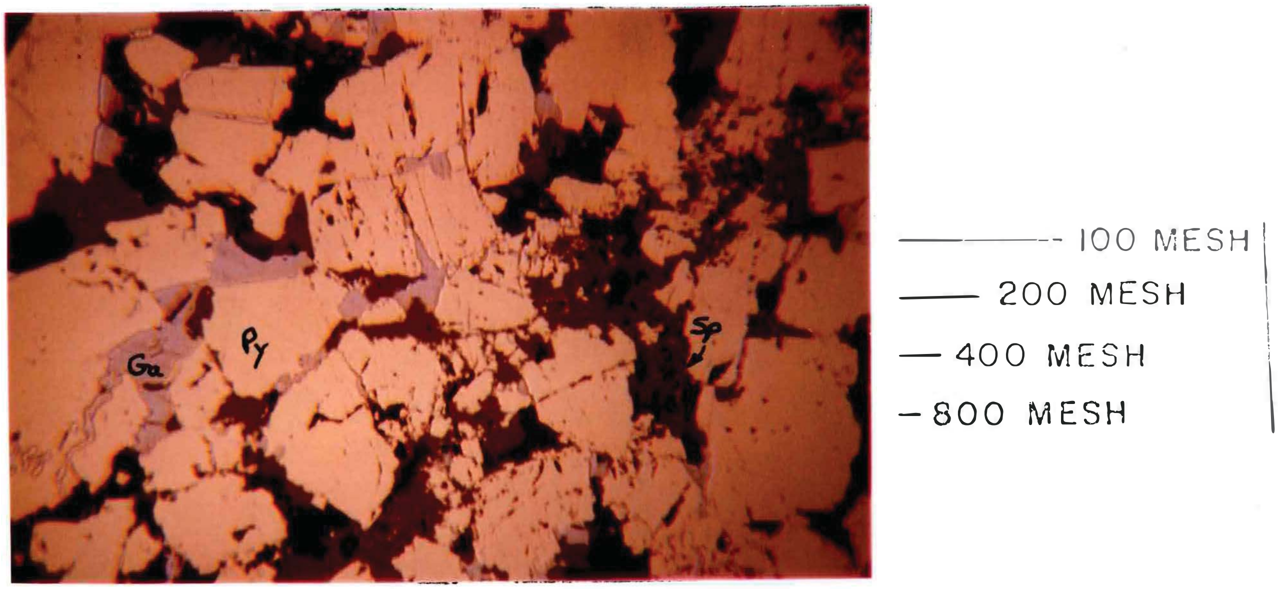


Figure 37 - Photomicrograph of High-Pyrite Ore (Mpy) From Site "A"---Metallurgical Sample 14

Note clean separation of galena and sphalerite (Ga/Sp=3) but more serious $\frac{\text{Ga}}{\text{Sp}}/\text{Py}=4$ rating. Some black limonite pits.

(4) it seems apparent from inspection of the metal contents of the tailings that oxidation is the main cause of Zn losses but cannot fully explain Pb losses. Samples 1, 3, 5 and 7 are all intensely oxidized. Therefore, lower Pb losses in sample 1 (Ga/Sp=3) than in 3, 5, 7 (Ga/Sp = 6), are probably due to the much less severe Ga/Sp middlings in the former. This is supported by the much higher grade of the Pb concentrate for sample 1. Because of the extemely fine size of galena in samples 3, 5, and 7, much galena is slimed and is lost to the tailings.

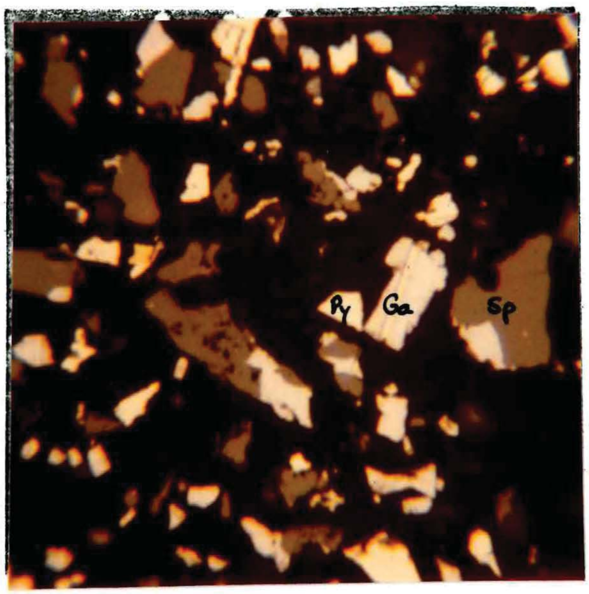
(5) study of Pb grades and Pb/Zn ratios in the Pb concentrates shows conclusively that the Ga/Sp middlings problem is the main cause of Zn contamination of Pb concentrates. In the highly oxidized "poor" group, sample 1 yields a much better Pb concentrate than samples 3, 5 and 7 because it has a normal Ga/Sp rating of 3 whereas the others rate 6. Similarly, in the intermediate group, sample 14 with Ga/Sp = 3 gives a better lead concentrate than 4, 6, or 8 in which Ga/Sp = 5. Finally, the acceptable group, 2, 9, 10, 11, 12, 13 all have low Ga/Sp ratings and give better Pb concentrates than samples of the other two groups.

The composite sample (Table III) is a combination of most of the fourteen samples, and as far as ore-types are concerned, it is roughly representative of the entire Grum deposit. However, due to necessity, the 7% MV was derived from highly oxidized sites "B" and "F", and the 6% from site "B" has the extreme Ga/Sp = 5-6 middlings. Tests should show if these portions spoil the entire sample.

Table III - Analyses and Geological and Metallurgical Data for Samples 1-14 From Sites A-I

No.	Site	ORE TYPES (Samples~10 kg)	S.G.[1]	Pb[1]	Zn[1]	Au[1] oz/t	Ag[1,4] oz/t	Cu[1]	As[1]	Hg[1,4] ppm	SiO_2[1]	S_2O_3[1] ppm	Ox[5] (est)	Py (est)	Tn[4] (est)	Ga/Sp[5]	Ga/Sp/Py	Ga/Sp/Gm	Pb.R.Con.[1]		Zn.R.Tail[1]		METALL CLASS	% of Composite
																			Pb	Zn	Pb	Zn		
1	F	90% MV, 10% Mpy	4.5	6.9	14.4	.036	3.0	.10	.33	183	0.7	158	10	55	1/4	3	3	3	31.86	15.74	1.54	13.64	Poor	3
2	F	70% M_Q, 10% Mpy	3.6	6.5	18.9	.032	3.5	.02	1.36	192	34.6	41	1	20	1/4	3	2	3	56.78	13.14	0.36	0.34	Accept.	11
3,5,7[2]	B	80% MV, 20% Mpy	4.3	8.7	13.3	.047	4.4	.28	.29	154	7.2	600	8	45	Tr	6	3	3	20.53	17.60	2.95	11.45	Poor	4
4,6,8[3]	B	75% M, 15% M_Q 10% Mpy	4.2	8.8	15.2	.043	3.8	.08	.42	146	11.6	149	2	40	-	5	2	3	20.77	16.39	0.87	0.67	Interm.	2
9	E	65% MI, 25% M_Q-P 10% Mpy	3.9	9.1	16.3	.055	5.9	.09	.10	267	12.7	96	0	35	1/2	3	2	3	27.47	16.53	1.20	0.72	Accept.	5
10	G	100% P	2.8	1.5	3.2	.012	0.6	.03	.02	33	72.7	6	0	8	-	2	2	5	18.35	6.06	0.29	0.22	Accept.	20
11	D	75% P, 25% Mpy	3.0	3.3	6.6	.020	1.7	.08	.23	91	58.2	46	1	17	-	1	2	4	38.11	8.27	0.56	0.26	Accept.	20
12	I	95% M_Q-P, 5% Mpy	3.4	4.8	9.0	.027	2.3	.06	.21	114	44.6	84	0	25	-	3	2	3	39.70	10.04	0.67	0.39	Accept.	20
13	C	75% P-M_Q, 25% Mpy	3.6	2.8	4.5	.036	1.2	.04	.42	49	39.2	74	1	35	-	2	3	3	34.6	3.45	0.60	0.67	Accept.	15
14	A	90% Mpy, 10% M_Q-P	4.4	8.6	5.8	.049	3.0	.18	.04	17	3.5	246	2	60	-	3	4	3	25.65	13.76	1.84	0.27	Interm.	0
-	H	P + M_Q	-	5	9	← estimates only →							1/2	20	-	2	3	2	-	-	-	-	No Test	-

1 - Analyses done by Mattagami Lake Mines Ltd.-- Reports by K.V. Konigsmann and K. Stowe referred to on page 15.
2 - Samples 5 & 7 are similar to sample 3 except for addition of 1 Kg fault gouge (5) and 1 Kg graphitic phyllite (7). Analyses are averages.
3 - Samples 6 & 8 " " " " 4 " " " " " " " (6) " " " " (8). " " "
4 - Tn=tennantite=$(Cu, Fe, Zn, Ag, Hg)_{12}(As, Sb)_4S_{13}$. Tn carries the Hg, and probably much of the Ag.
5 - Ox and Ga/Sp relate closely to recoveries (tailings losses) and concentrate grades.



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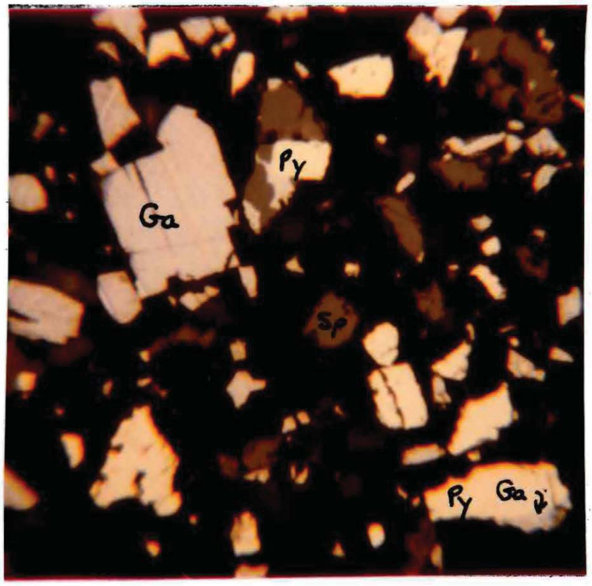

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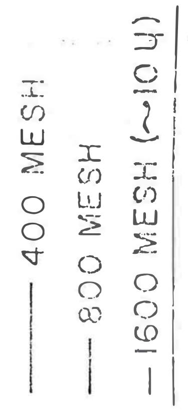

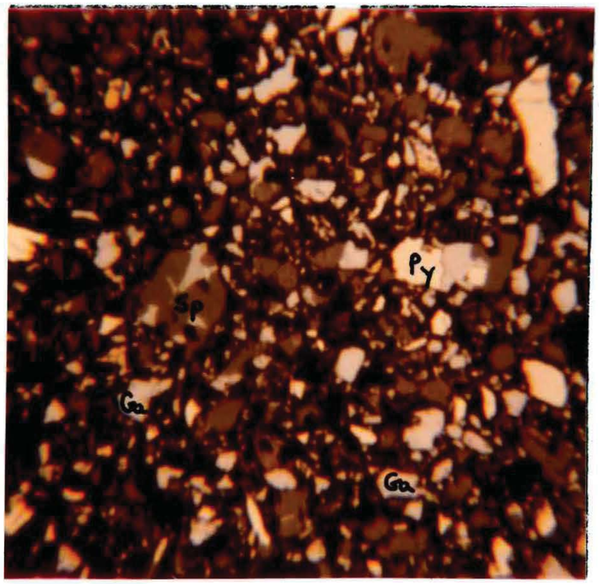

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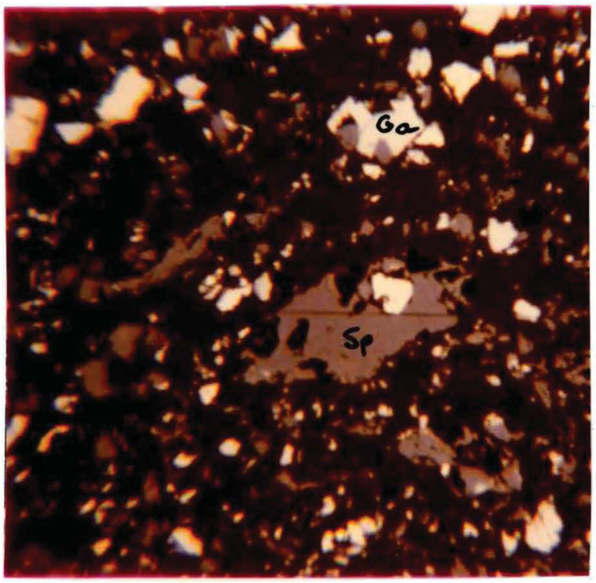


41

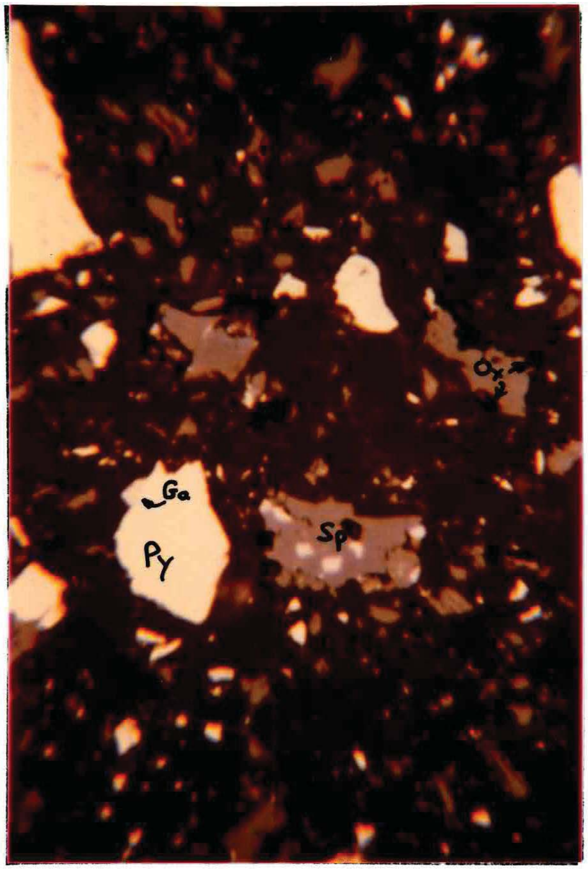
Figures 38, 39 - Lead Concentrate - 4 Cycle, Sample B_4 (39.9% Pb, 8.8% Zn)

Note Ga/Sp, Ga/Py and Ga/Sp/Py middlings - about 60% of the sphalerite grains have visible attachments of galena. Therefore, most sphalerite grains have galena attachments because many small attachments are not in the exact plane of the polished section.

Figure 40, 41 - Lead Concentrate - 6 cycle, Sample B_3 (38.1% Pb, 20.08% Zn)

Note Ga/Sp and Ga/Py/Sp middlings, sphalerite with oxide pits and coatings, and chalcopyrite (yellow). The sphalerite-oxide fragment with the included pyrite crystal in Figure 41 has a few small visible galena inclusions and there are probably additional inclusions below the plane of the polished section. Oxide appears to have either activated sphalerite, or else desensitized its depression thereby making galena inclusions more effective in pulling it up during lead flotation.

PHOTOMICROGRAPHS OF LEAD SCAVENGER CONCENTRATE AND LEAD CLEANER SCAVENGER TAILING



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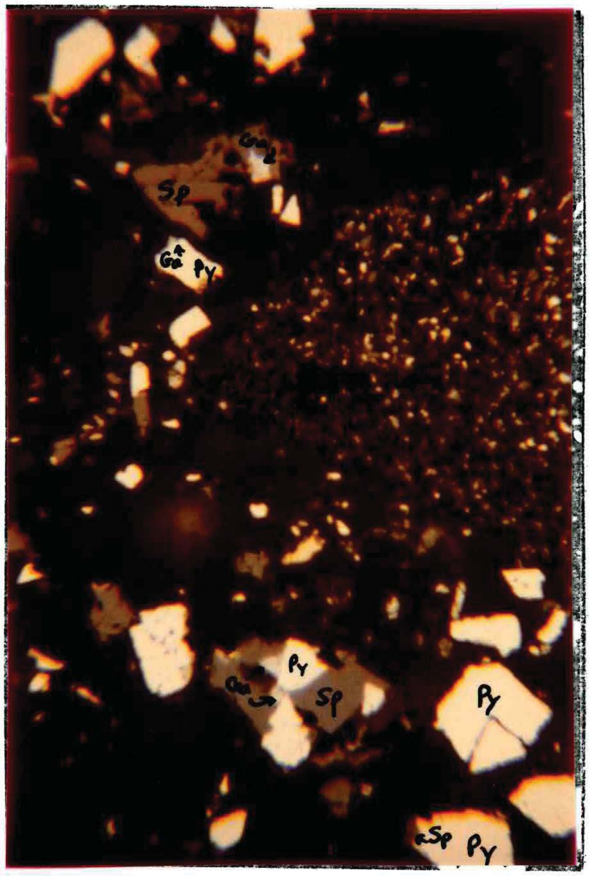

43

——— 400 MESH

—— 800 MESH

– 1600 MESH (~10 μ)

Figure 42 - Lead Scavenger Concentrate, Sample B_3 (Pb=7.2%, Zn=22.3%)

Note Ga/Sp/Ox and Ga/Py middlings. Oxide (black) shows preference for sphalerite.

Figure 43 - Lead Cleaner Scavenger Tailings - 5 Cycle, Sample B_4 (Pb=10.9%, Zn=10.0%)

Note Ga/Sp, Ga/Sp/Py, Ga/Py, and Sp/Py middlings, and Sp+oxide coatings and pits. Pb losses are due to very fine (±5 microns) slimed galena, much of which is in the clot of fine grains.

PHOTOMICROGRAPHS OF ZINC CONCENTRATE

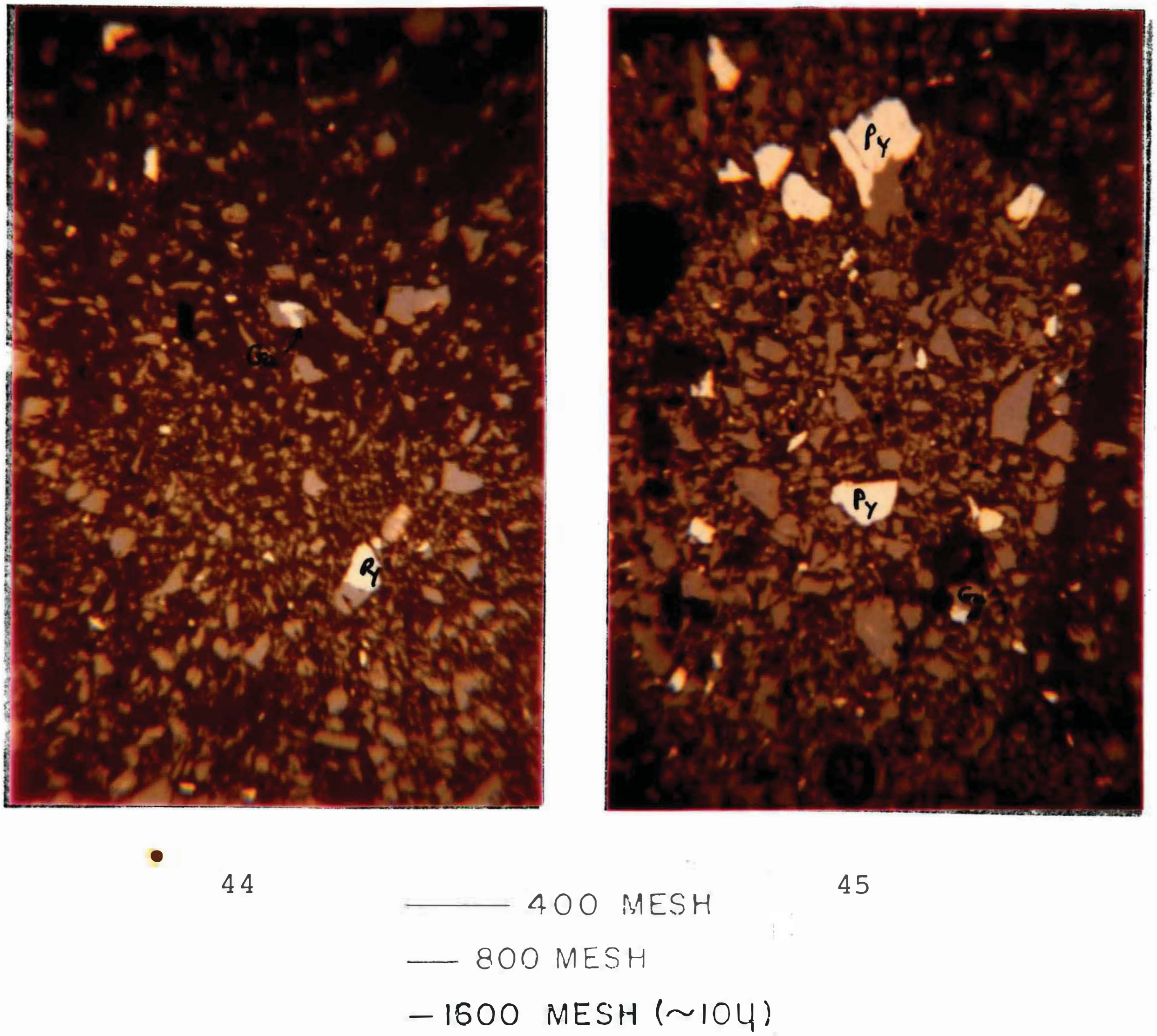

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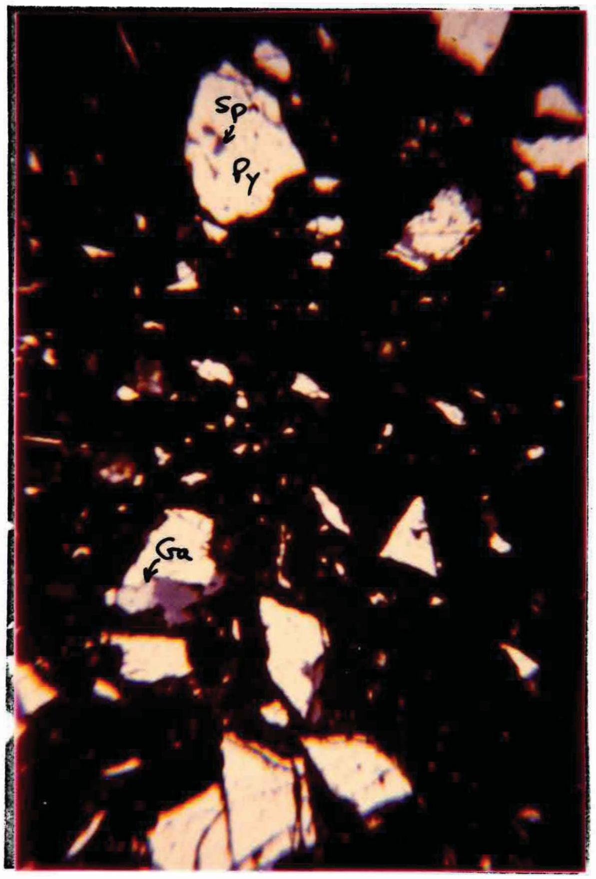
Figure 44, 45 - Zinc Concentrate - 6 Cycle, Sample B_3
(Pb=1.8%, Zn=54.4%)

Note relative purity of the concentrate except for minor Ga/Sp and Sp/Py middlings, and Sp/Py/Ga middlings (Figure 44), and some very fine (±5 micron) pyrite and slimed galena. Also, one (yellowish) Cp/Sp middling grain (Figure 45). Nearly all the chalcopyrite floats into the lead concentrate (Figure 40).

PHOTOMICROGRAPHS OF TAILINGS



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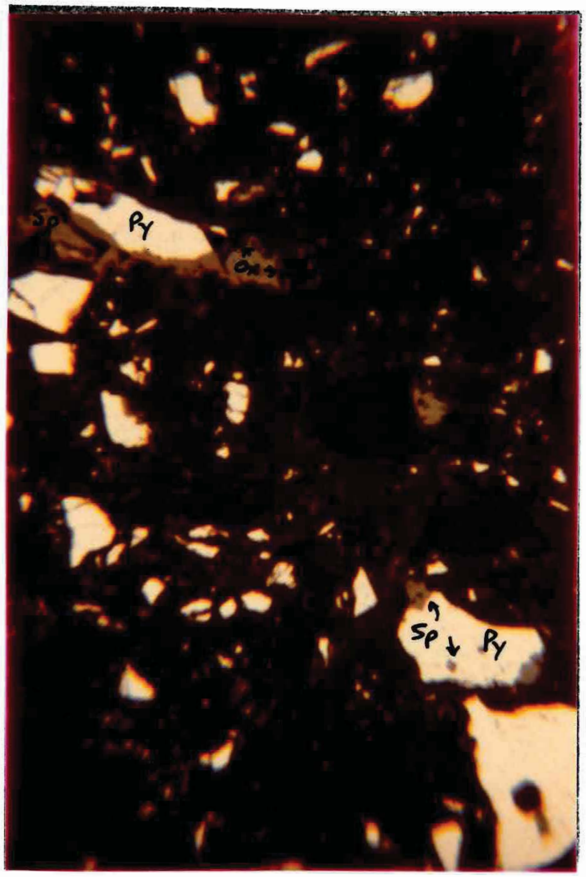

47

—— 400 MESH
— 800 MESH
— 1600 MESH (~10μ)

Figures 46, 47 - Zinc Rougher Tailings - 6 Cycle, Sample B_4 (Pb=1.11%, Zn=2.22%)

Abundant Sp/Py middlings; $^{Ga}_{Sp}$/Py middling grain, Figure 46; Ga/Gm and Sp/Gm middlings grains (both in quartz) Figure 47 (center). Many sphalerite grains in the tailings are coated with oxide (Figure 47).

Abundant Gm (gangue) fragments are seen faintly in Figure 46 but more clearly in Figure 47.