007219

# Vancouver Petrographics Ltd.

**JAMES VINNELL,** Manager
**JOHN G. PAYNE,** Ph.D. Geologist
**CRAIG LEITCH,** Ph.D. Geologist
**JEFF HARRIS,** Ph.D. Geologist
**KEN E. NORTHCOTE,** Ph.D. Geologist

P.O. BOX 39
8080 GLOVER ROAD,
FORT LANGLEY, B.C.
V0X 1J0
**PHONE (604) 888-1323**
**FAX. (604) 888-3842**

Report for: Gordon Wilson,
Chief Metallurgist,
Curragh Resources Inc.,
Box 1000,
Faro, Yukon,
Y0B 1K0

Job 111

November 21st, 1990

## MINERALOGICAL STUDY OF SAMPLES FROM THE FARO LEAD-ZINC OPERATION, YUKON TERRITORY

### Introduction:

The following samples were submitted for polished thin section preparation and microscopic examination.

Head Samples (crushed material)
- Faro Pit 1
- Faro Pit 2 (V-DT-12)
- Faro Pit 3 (DL-08)
- Faro 4 (Drill Cores)

Concentrates
- Pb Concentrate 1
- Pb Concentrate 2

Tailings
- Pb Tailings 1
- Pb Tailings 2

Rock Samples
- V90-DT-12
- V90 PL-01

Hole V90-12
- 60044, 60047, 60051, 60053

Hole V90-79
- 60418, 60419, 60421, 60423

**Background and Objectives:**

The majority of these samples come from a new ore body to be brought into production at the Faro operation. Initial metallurgical tests on drill core suggested no particular problems in mill treatment of this ore. However, subsequent testing on the stripped ore body indicated severe treatment problems with certain samples, suspected to relate to localized oxidation and/or leaching.

Such samples are characterized by a failure to achieve separation of galena from sphalerite. Instead of a specific concentrate of galena being obtained in the Pb flotation stage, sphalerite also floats - producing a bulk concentrate. Apparently the sphalerite (which normally requires activation by the addition of Cu $SO_4$ to cause it to float) is somehow self-activated in these aberrant samples. The principal objective of the present study is to develop a mineralogical explanation for this behaviour.

The head sample designated Faro Pit 1 represents typical material of the original ore body.

Head sample Faro Pit 2 (V-DT-12) typifies material from the new ore body which exhibits normal processing characteristics. Pb Concentrate 1 and Pb Tailings 1 represent products from the milling of this ore type.

The head samples designated Faro Pit 3 (DL-08 PL-08) and Faro 4 (drill cores) are ore types from the new ore body which exhibit aberrant treatment characteristics. Pb Concentrate 2 and Pb Tailings 2 represent products obtained from the treatment of such material.

The suite also includes a comparison pair of two grab samples of ore from the new ore body (V90 PL-01 and V90 DT-12). These both come from the 1140 bench - the first at location 27E and the second at 16E. PL-01 is vuggy, and behaves badly in flotation, yielding a bulk product. DT-12 is non-vuggy and behaves conventionally, with good separation of Pb from Zn at the Pb rougher stage.

The remainder of the suite consists of various ore types from the new ore body, as differentiated in the logging of drill holes V90-12 and V90-79. No information was provided re their specific treatment characteristics.

**Summary of Mineralogical Observations:**

The ore samples making up this suite exhibit the following general characteristics. They are massive to semi-massive sulfide aggregates consisting predominantly of pyrite, sphalerite and galena, intergrown with a gangue composed of varying proportions of barite, quartz and carbonate. Primary accessory constituents (not necessarily present in all of the samples) are pyrrhotite, marcasite and magnetite. Low levels of chalcopyrite (from traces to about 0.5%) are observed in most samples.

Most commonly the pyrite occurs as subhedral individuals, more or less densely disseminated through a matrix of gangue with intimately intergrown fine-grained sphalerite and galena. Occasionally the pyrite forms a compact aggregate in which gangue and Pb/Zn sulfides constitute a minor interstitial/cementing phase. The scale of intergrowth of the galena and sphalerite with the gangue and pyrite ranges from a few microns up to a few hundred microns.

Samples Faro Pit 1, Faro Pit 2 (V-DT-12), V90 DT-12, 60051, 60053, 60419, 60421 and 60423 are all of this general type, though varying in mineral proportions, grain size, Pb/Zn grade and textural details (see individual descriptions and photomicrographs).

Sample 60418 consists predominantly of pyrrhotite (and derived secondary pyrite and marcasite).

Samples Faro Pit 3 (DL-08), Faro 4 (drill cores), V90 PL-01, 60044 and 60047 are of similar general character to the main group (except that 60044 is unusually low in total sulfides). However, they all exhibit a characteristic alteration of the contained galena.

This alteration ranges from a diffuse dustiness or mottling of the galena, through distinct rims and cellular textures of a low reflective secondary product, to areas of soft, non-polishable, porous material - sometimes packed with relict specks and meshworks of galena.

This effect is strongly concentrated in the galena, but commonly extends into the associated sphalerite as micron-scale rims and grain-boundary networks. The material of these features is often quite highly reflective and looks like actual galena (or some other sulfide) rather than an oxidized/secondary product.

Fine-grained, bluish material, having the appearance of secondary-type, enriched Cu sulfides (probably mainly intergrowths of chalcocite and digenite), is sometimes associated with the galena alteration, or forms clumps, rims and threads in the associated sphalerite.

It is notable that the distribution of the secondary-type Cu does not seem to be spatially related to the accessory chalcopyrite. The latter often occurs in minor quantities in the same samples, but is almost always fresh.

Two of the samples in this altered group (Faro 4 and 60044) show an additional feature. In these the pyrite grains are often strongly shattered, and veined by galena. They also appear to show varying degrees of replacement - yielding areas of galena speckled with tiny pyrite remnants. Occasionally sphalerite appears to be similarly affected.

**Nature and Origin of the Alteration:**

The small scale and intimate, often diffuse textural character of the galena alteration and the associated sphalerite-rimming

phenomenon makes determination of the specific mineralogy of the constituent phases very difficult.

X-ray diffraction scans were run on three of the altered samples. This is a bulk method, the effectiveness of which depends on the concentration of the species sought, and is lowest in multi-component mixtures. No recognizable response from the secondary products was obtained in 60044 and 60047, but small peaks, possibly attributable to anglesite, were obtained in PL-01.

The application of micro-analytical techniques, like scanning electron microscopy or electron microprobe analysis, also has limitations for the elucidation of the alteration mineralogy. The intricacies of the intergrowths, the swamping effect of the major components (Pb, Zn and Fe), the difficulties of differentiating Pb from S because of overlapping spectral peaks, and the inability to detect C (as in Pb and Zn carbonates) by XRF because of its low atomic number, are all factors which combine against the effective use of such methods.

Probe work remains the best available possibility of obtaining additional information, but only in the context of a research-quality study.

The total absence (in the study samples) of limonitization of the ubiquitous pyrite suggests that the observed alteration did not take place under surface-related conditions of oxidation and weathering. Rather, the presence of the S-depleted Cu sulfides chalcocite, digenite and covellite (albeit in minor proportions) is characteristic of the zone of secondary enrichment. This is considered to have formed under oxygen-free conditions, probably at, or just below, the water table in deposits whose higher levels were undergoing active oxidation, yielding downward-percolating, metal-rich solutions. In the present case the hypothetical oxidized zone would appear to have been removed by erosion.

The strong preferential alteration of galena observed in the present samples is, however, atypical of this mechanism. Cu (and Ag) are the two elements commonly transported and reprecipated as enriched species. Pb is not known to be affected. Another point to be considered is that secondary enrichment does not usually take place in deposits containing significant amounts of carbonate (which tends to neutralize the acidic solutions produced in oxidation of sulfides and fix the liberated metals in the oxidized zone.

**Metallurgical Implications**

Altered galena, sphalerite grains with rims of remobilized galena, and blue secondary-type Cu sulfides are all notable constituents in the two mill-test samples (Pb concentrate 2 and Pb Tailings 2) known to exemplify poor flotation behaviour.

These same constituents are absent from the ore samples known to behave normally in flotation. One or all of them are thus indicated as a possible cause of the treatment problem. By extension,

material of the types represented by the remaining rock samples (60051, 50053, 60419, 60421 and 60423 - and possibly 60418) are considered unlikely to present a treatment problem (over and above any limitations stemming from fineness of grain).

Observations on the concentrate and tailings produced from the "difficult" ore indicate two principal peculiarities. Not only is the intended Pb concentrate grossly contaminated with Zn (sphalerite being some 6 times as abundant as galena), but the tailings still contain substantial galena; i.e. it would appear that the flotation of galena is inhibited, as well as that of sphalerite being enhanced.

However, the observations do not support the conclusions that the altered form of galena consistently fails to float, whilst the unaltered portion floats normally. Neither does it appear true that the sphalerite grains with rims (or surface films) of galena(?) float whilst the normal sphalerite remains suppressed. Both fresh and altered types of both minerals are found in both products (see photomicrographs).

Of the mechanisms suggested in your letter, the presence of soluble salts in the ore is difficult to explain in a present-day, non-desert, near-surface environment. However, it may be that the prevailing permafrost conditions contribute in some way (preventing the leaching out of soluble products?). In any event, such an effect is unlikely to involve Pb salts, most of which are notably insoluble.

Your experimental findings that a substantial proportion of the Cu in these aberrant ores is water-leachable is surprising. If this is a consistent feature, it may well contribute to the flotation problem. The solubility of part of the Cu in cyanide is less surprising, being explained by the observed presence of chalcocite/digenite/covellite.

My observations do not suggest a correlation of Cu content <u>per se</u> with aberrant flotation properties, but they do indicate that the presence of enriched secondary-type Cu sulfides is characteristic of the "bad" ore, whereas small quantities of chalcopyrite are present in almost all the samples, irrespective of type. I suspect, therefore, that total Cu may prove a less precise screening criterion than cyanide-soluble (or possibly water-soluble) Cu contents.

The present study provides partial explanation of your finding that improved flotation behaviour is achieved if the undersize portion is removed at the fine crushing stage. The most strongly altered galena appears to be of a soft, fragile, porous nature, and may well concentrate in the fines at the crushing stage. However, there is no particular indication from the textural relationships that the rimming effects in the sphalerite, and the more diffusely altered galena, would behave in this way. In any event, these altered forms have not been shown to behave consistently as regards their

flotation properties. Useful information might be obtainable from microscopic examination of some of the improved products achieved by this approach.

Individual mineralogical descriptions are attached, together with a set of illustrative photomicrographs. The latter provide a visual comparison of the salient features of the different samples in the suite, with special emphasis on the alteration process which appears, in some way, to influence the flotation properties of the ore.

J.F. Harris Ph.D.

((604) 929-5867)

## PHOTOMICROGRAPHS

All photos are by reflected light at a scale of 1cm = 85 microns, except where otherwise stated.

### A. METALLURGICAL PRODUCTS: Good Treatment Characteristics

**HEAD SAMPLE: FARO Pit 1**

**Neg. 187-0:** Typical field. Mineral fragments (crushed ore) as follows: cream colour is pyrite; light blue-grey (e.g. composite with pyrite at right centre) is galena; dark grey (e.g. intergrown with galena, and as free grain at bottom right) is sphalerite; yellow (selvedge on pyrite grain at upper left) is chalcopyrite; light brown (centre top) is pyrrhotite. Speckled, cream-coloured grain at far left is secondary pyrite/marcasite, after pyrrhotite. This colour key applies to all the photographs.

**Neg. 187-1:** Part of a large fragment (colour key as for 187-0). Shows typical texture of subhedral pyrite grains (cream colour) in matrix composed of gangue (darkest grey: e.g. centre) with intergrown pockets of base metal sulfides: e.g. galena and sphalerite at left; sphalerite and chalcopyrite at top right; sphalerite, galena and pyrrhotite at lower right centre. Note rounded to sub-angular inclusions of sphalerite (and occasional galena and chalcopyrite) in the pyrite grains.

**HEAD SAMPLE: FARO PIT 2 (V-DT-12)**

**Neg. 187-2:** Typical field. Note much finer scale of intergrowth than in previous sample. Fragment at left shows subhedral pyrite in matrix consisting of fine-grained intergrowth of sphalerite (medium grey), galena (light grey), and gangue (black). Fragment at bottom right is same components in somewhat coarser, equigranular intergrowth. Fragment at top right shows pyrite grains set in matrix of intergrown galena and sphalerite. Fragments at extreme right are gangue (barely distinguishable from the black background) with tiny interstitial flecks of sulfides.

**Neg. 187-3:** Field showing some other textural associations common in this sample. Large fragment at lower left is intimate, fine-grained intergrowth of galena, sphalerite, pyrrhotite and gangue. Elongate fragment at centre is of coarsely intergrown pyrite and sphalerite, but note tiny disseminated inclusions of galena in the sphalerite. Field includes some magnetite, similar in colour to sphalerite, but slightly browner-grey as opposed to the more bluish-grey sphalerite (e.g. bottom right; upper left; and as a few discrete clumps in the large polymineralic fragment at lower left).

**Pb CONCENTRATE 1**

**Neg. 187-17:** Scale 1cm = 42 microns. Typical field. Cream colour is pyrite; light bluish grey is galena, medium grey is sphalerite; dark grey is gangue (rare). Also note one or two tiny grains of chalcopyrite (yellow). The majority of particles are liberated, but careful examination shows relatively numerous examples of galena/sphalerite composites, and a few of pyrite/galena and pyrite/sphalerite.

**Neg. 187-18:** Scale 1cm = 42 microns. Another typical field. Colour key and comments as for 187-17. Average particle size in this area of the slide is slightly higher.

**Pb TAILINGS 1**

**Neg. 187-22:** Scale 1cm = 42 microns. Typical field, showing part of a flocculated clump of finer-sized particles (right) and an area of segregated coarser particles. Mineralogy consists of pyrite (cream colour), sphalerite (medium grey) and gangue (very dark, just distinguishable from the black background. Note lack of galena. The components are largely as liberated particles. Two sphalerite grains at lower left have small inclusions of pyrrhotite (buff colour).

**B. METALLURGICAL PRODUCTS: Bad Treatment Characteristics**

**HEAD SAMPLE: FARO PIT 3 (DL-08)**

**Neg. 187-4:** Typical field, showing various mineral fragments. Area at upper right is pyrite with intergrown marcasite (whiter), probably secondary after pyrrhotite; grey pockets are interstitial sphalerite. Irregular-shaped grain at bottom right is sphalerite (dark grey) with intimately intergrown galena (light bluish grey); this galena is of fresh, normal appearance. Compare the fragment at bottom left which consists of semi-massive pyrite with an interstitial/matrix phase of speckled grey material; the latter is also galena, but of pervasively altered type.

**Neg. 187-5:** Area at upper right consists of an intergrowth of sphalerite (dark grey) and gangue (darker grey) with scattered pyrite euhedra. Note sporadic blue patches; these are secondary Cu sulfides, predominantly digenite. Fragment at left centre shows pyrite with interstitial/cementing phase of minutely intergrown chalcopyrite, galena and sphalerite; note that this chalcopyrite shows no sign of alteration to blue secondary products. Fragment at bottom left is an example of homogenous sphalerite in relatively coarse-grained intergrowth with pyrite.

**Neg. 187-6:** Scale 1cm = 42 microns. Higher magnification shot of central area of Neg. 187-5. Shows example of a sphalerite grain (left centre) having a partial rim or surface film of apparent galena.

**HEAD SAMPLE: FARO PIT 4 (Drill Cores)**

**Neg. 187-7:** Typical field. Shows pyrite grains in matrix of gangue (darkest grey) with sparse pockets of sphalerite and galena. Many of the pyrite grains are fractured and cemented by an altered form of galena (note dusty, mottled appearance). In grains at bottom right and extreme left, the associated galena is speckled with bluish secondary Cu sulfides.

**Neg. 187-8:** Another typical field. Fragment at upper left consists of compact pyrite with interstitial chalcopyrite (yellow), shalerite (grey) and gangue (black); the chalcopyrite is fresh. Two diffuse-margined, light grey areas at right consist of galena showing speckling of secondary products, grading to completely altered peripheral zones (black). Black areas in the cores of these fragments are vuggy cavities from leaching or plucking of secondary products. Note presence of <u>fresh</u> chalcopyrite in the upper area of altered galena, and of intergrown patches of sphalerite in the other one.

**Neg. 187-9:** Scale 1cm = 42 microns. Similar subject matter to 187-7 (fractured pyrite cemented by weakly-altered galena), but higher magnification. Clearly shows rimming of adjacent sphalerite grains by networks of remobilized(?) galena.

**Neg. 187-10:** Scale 1cm = 42 microns. Detailed shot of area of galena speckled with tiny remnants of pyrite - assumed to represent the unreplaced remains of grains which were originally like the two coarser pyrite individuals. The galena shows strong marginal alteration, grading to a low-reflective (dark) secondary product, more or less densely dusted with tiny flecks of surviving galena.

**Neg. 187-11:** Scale 1cm = 42 microns. Examples of other manifestations of the alteration process. Grain of coarse galena (light grey with triangular black cleavage pits) at top right has colloform-textured rind of altered material - incorporating remnants of fresh pyrite and chalcopyrite. Sphalerite grain at centre bottom has an almost complete, thin rim of apparent galena. Larger sphalerite grain at top left also has a rim, in this case of bluish, presumably Cu-rich material.

**Neg. 187-12:** Scale 1cm = 42 microns. Area of galena showing peripheral gradation, via speckled/mottled zones, to non-reflective and partially leached (black) altered material with lamellar remnants of galena. Note intimate complex contact relationships (replacement?) of the partially altered (secondary?) galena with the patches of intergrown sphalerite (e.g. lower centre; bottom left). The grinding of such material will clearly yield sphalerite particles rimmed by galena.

**HEAD SAMPLE: FARO PIT 4 (Drill Cores)**

**Neg. 187-13:** Scale 1cm = 42 microns. Another textural variant of the feature illustrated in 187-10. An extensive area of galena is packed with minute angular shards (presumed replacement remnants) of pyrite. At upper right the galena shows complex margins representing alteration to porous, partly leached secondary products. The main area of galena shows diffuse partial alteration to grey material, including colloform/concentric textures. Note small included grain of chalcopyrite (lower right); this is fresh and apparently unaffected by the galena alteration process.

**Neg. 187-14:** Scale 1cm = 42 microns. Area of diffusely altered (mottled) galena with concentric zonal textures around inclusions of sphalerite (partly replaced?). Field also includes fragment of sphalerite (dark grey) at lower left showing altered periphery with flecks of blue secondary Cu sulfides. Note that pyrite, as always, appears unaffected by these alteration effects.

**Neg. 187-15:** Scale 1cm = 42 microns. Apparent rim replacement of pyrite (cream colour) by pyrrhotite (brownish). Partly pyrrhotitized pyrite also occurs (right and lower left) as small islands in a matrix of intensely altered galena. The galena (light grey) shows peripheral gradation to non-reflective secondary material with minute needles of relict galena. At upper left the relict galena shows parallel lamellar form.

**Neg. 187-16:** Scale 1cm = 42 microns. Detailed view of textural relationships as shows in Negs 187-7 and 9. Shows fractured pyrite (left) veined by galena (and possibly some pyrrhotite) and mantled by an area of segregated galena speckled with tiny angular shreds of pyrite (presumably unreplaced remnants). Sphalerite grain (dark grey) at bottom right has galena rims, but so thin (<1 micron) as to be virtually indistinguishable in the photograph.

**Pb CONCENTRATE 2**

**Neg. 187-19:** Scale 1cm = 42 microns. Compare with Pb Concentrate 1 (Negs 187-17, 18). This product (of notably fine particle size) consists largely of sphalerite (medium grey). Galena (light bluish grey) is minor. Note also presence of relatively coarse grains of free pyrite (cream colour). Gangue (dark grey) is relatively abundant.

**Neg. 187-20:** Scale 1cm = 21 microns. Maximum magnification to show details. Galena rimming on sphalerite grains is fairly common (e.g. lower right centre; upper right centre). Product includes accessory proportions of blue secondary Cu sulfides, typically as very tiny particles.

**Pb CONCENTRATE 2**

**Neg. 187-21:** Scale 1cm = 21 microns. Similar features to 187-20. Note galena rim on relatively large, equant sphalerite grain at centre right. Irregular, speckled, light grey grain at centre is altered galena. Sphalerite grain at lower right centre has a rim of blue secondary Cu sulfides. Field also includes a grain of fresh chalcopyrite (yellow; upper left).

**Pb TAILINGS 2**

**Neg. 187-23:** Scale 1cm = 42 microns. Field includes flocculated fines (upper left, bottom right) separated by area of segregated coarser particles. Note presence of several grains of galena (light bluish-grey) in this central zone. These show partial speckling, indicative of incipient alteration. Field also includes a small grain of chalcopyrite (yellow; bottom left) - which, along with the galena, should have gone into the Pb concentrate rather than remain in the tailings.

**Neg. 187-24:** Scale 1cm = 21 microns. Maximum magnification to show details. Note presence of galena (mostly apparently fresh) as essentially free grains (e.g. upper left, bottom right), and composite with sphalerite (top right). Galena is also a minor component of the floc of finer particles at lower left.

**Neg. 187-25:** Scale 1cm = 21 microns. Shows presence of sphalerite grains rimmed by galena (upper right) and by altered galena with intergrown blue Cu sulfides (top left, bottom right). Apparently such material does not necessarily float readily. Field also includes galena of fresh, normal appearance (e.g. bottom left; top right centre), and a grain of fresh chalcopyrite (upper left centre). Note relatively high content of gangue particles (very dark grey, just distinguishable from the background), mostly free of sulfides.

**C. ROCK SAMPLE : Good Treatment Characteristics**

**SAMPLE V90 DT-12**

**Neg. 188-0:** Typical field. Shows equant pyrite individuals in matrix of gangue (dark), with irregular impregnations of sphalerite (medium grey) and fine-grained galena (light bluish grey). Pyrite grains sometimes show saw-tooth margins, embayed by the matrix sulfides. Note inclusions of sphalerite in a few pyrite grains.

**Neg. 188-1:** Another typical field. Similar features to 188-0. Note very fine scale of intergrowth of galena with gangue and sphalerite. This will necessitate very fine grinding for adequate liberation.

**D. ROCK SAMPLE : Bad Treatment Characteristics**

**SAMPLE V90 PL-01**

**Neg. 188-2:** Typical field. Compare with 188-0 (DT-12). Style of intergrowth is essentially the same, but on a relatively coarser scale. This field also exemplifies a mild manifestation of the alteration of galena. Note grey altered phase (darker than galena, lighter than sphalerite) as occasional threads and spots in galena, and as rims at contacts of galena with sphalerite, gangue or pyrite (e.g. centre bottom; left centre).

**Neg. 188-3:** Example of stronger development of galena alteration as described for 188-2. Fresh galena survives as remnants rimmed by - or as small cores in cellular boxworks of - the lower reflectivity secondary product.

**Neg. 188-4:** Scale 1cm = 42 microns. Higher magnification, to show details of galena alteration. Note intergrowth of specks and concentric zones of blue secondary Cu sulfides in the altered galena at lower left. Sphalerite adjacent to altered galena at right shows thread-like networks and minutely thin rims of apparent (remobilized?) galena, locally somewhat bluish. Rims and intergranular threads in the sphalerite grain at top left are more obviously blue and clearly consist mainly of secondary Cu sulfides. Pyrite is strikingly unaffected by the alteration.

**Neg. 188-5:** Scale 1cm = 42 microns. Detailed view, showing diffuse nature of intergrown blue Cu sulfides in concentrically zoned alteration of galena (at left). Field also includes a relatively coarse area of largely unaltered galena (upper centre).

**Neg. 188-6:** Scale 1cm = 42 microns. Example of Cu-rich (blue) alteration concentrating in sphalerite (medium grey, upper part of field). The adjacent galena is locally strongly altered in the colloform/crustified style prevalent in this sample (centre top), but more often (extreme right, upper left) is unaltered. Note blue Cu sulfides as acicular growths in carbonate gangue (medium-dark grey) at bottom right of centre; and as cluster of small granules in pocket of totally altered material (black) at bottom, left of centre.

**E. ROCK SAMPLES: Mineralogy Suggesting Normal Treatment Properties**

**SAMPLE 60051**

**Neg. 188-14:** Typical field. Pyrite aggregate at lower left is cemented by marcasite (slightly lighter in colour) and flecks of galena. Right half of field is a segregation carbonate (black) studded with pyrite grains, and having minor intergrown sphalerite (dark grey). Relatively coarsely segregated pockets of galena occur in the contact zone. Grey, high relief area at upper left is magnetite.

**SAMPLE 60051**

**Neg. 188-15:** Similar general features to 188-14, but here the pyrite aggregate is cemented by galena, and the carbonate segregation (left half of field) is free of pyrite and contains abundant intergrown sphalerite and galena. Ragged buff-coloured area at bottom left is pyrrhotite.

**SAMPLE 60053**

**Neg. 188-16:** Typical field. Shows wide size-range of pyrite, grading down to tiny granules (left). Note "frilled" margins of coarser pyrite grains - probably representing overgrowths of tiny granules. Interstitial/matrix phases are minutely intergrown galena, sphalerite and gangue. Fine grinding will be necessary for adequate liberation in this style of ore.

**Neg. 188-17:** Similar features to 188-16 but including slightly coarser pockets of sphalerite (right) and galena (bottom left). Minute disseminated specks of exsolved chalcopyrite are visible (in strong illumination) in the sphalerite at upper right.

**SAMPLE 60418**

**Neg. 188-18:** Typical field. Shows abundance of pyrrhotite (buff colour). This is extensively altered, and probably occurs as remnant cores in cellular/concentric growths of secondary pyrite/marcasite. The black patches and flecks in the latter are pits, indicating its porous character. Field includes relatively coarse segregations of sphalerite (medium grey), locally with included clusters of fine-grained pyrrhotite and galena. Note rare, angular individuals of fresh pyrite (e.g. upper centre).

**Neg. 188-19:** Another typical field of this unusual, pyrrhotite-rich ore type. Similar to 188-18, but also includes extensive areas of "dusty" brownish secondary-type pyrite (lower right), and patches of platy-textured, porous marcasite (whitish; upper right centre).

**SAMPLE 60419**

**Neg. 188-20:** Typical field. Note simple mineralogy and textural features. This material appears similar to Faro Pit 1, head sample, but has somewhat finer overall grain size.

**SAMPLE 60421**

**Neg. 188-21:** Typical field. Compare with 188-20 and note wide range of pyrite grain size, including some minutely granular material in intimate intergrowth with galena. This resembles Sample 60053 (see Negs 188-16, 17). The mineralogy is the same as that making up the majority of samples in this suite: i.e. pyrite, gangue, sphalerite and galena.

**SAMPLE 60421**

**Neg. 188-22:** Scale 1cm = 42 microns. Higher magnification to show details of the fine-grained intergrowth - parts of which appear unlikely to be fully liberatable.

**SAMPLE 60423**

**Neg. 188-23:** Typical field. Low-grade material consisting of compact pyrite with interstitial pockets of gangue (black) and minor sphalerite (dark grey).

**F. ROCK SAMPLES: Mineralogy Suggesting Aberrant Treatment Properties**

**SAMPLE 60044**

**Neg. 188-7:** Typical field. Aggregate of gangue (very dark grey) with pockets of sulfides consisting of fractured pyrite mantled and veined by mildly altered (partly dusty-looking) galena. The galena includes islands of sphalerite (medium grey), often surrounded by swarms of tiny granules of the same mineral. This texture could be interpreted as the result of partial replacement of sphalerite by the galena. Note similarity of this sample with the Faro Pit 4 head sample (Negs 187-7, 9).

**Neg. 188-8:** Area of strongly altered galena with dusty patches and colloform growths, grading to porous secondary material (black) with tiny flecks of remnant galena. Note rounded relict grains of sphalerite in the altered galena patch at centre bottom. Cream-coloured grains at lower right are fractured pyrite cemented by altered galena.

**Neg. 188-9:** Transmitted light. Same field as 188-8. Shows cellular and spongy texture of altered galena (white speckles are pores). Orange patches are sphalerite. Clear white patches are grains of barite or quartz. Black (opaque) is pyrite, galena.

**SAMPLE 60047**

**Neg. 188-12:** Typical field. Rather rounded, crenulate-margined pyrite grains are disseminated though a matrix of galena with abundant islands of sphalerite. This sample is essentially devoid of gangue. The black areas in the photograph are holes - representing natural vugginess, possibly emphasized by plucking during polishing. These areas may be localized centres of complete alteration(?) and leaching in a galena/sphalerite intergrowth in which the remaining galena appears largely fresh.

**Neg. 188-13:** Another area of the sample (contrast with 188-12). Galena (interstitial to pyrite) shows almost total conversion to low reflective (dark grey) porous secondary products. Note minor accessory chalcopyrite (yellow) as veinlet in pyrite (top) and random tiny grains (extreme left). The chalcopyrite is fresh, despite wholesale alteration of the associated galena.

**HEAD SAMPLE: FARO PIT 1**

Estimated mode

| | |
|---|---|
| Pyrite | 60 |
| Sphalerite | 10 |
| Galena | 3 |
| Chalcopyrite | 0.3 |
| Pyrrhotie | 1 |
| Marcasite | 3 |
| Quartz | 9 |
| Barite | 13.5 |
| Carbonate | trace |

This polished thin section consists of crushed fragments in the size range 0.02 - 2.0mm. The finer fractions tend to be liberated mineral grains, but the coarser fragments show something of the range of textural intergrowths present.

The ore is clearly of a predominantly pyritic nature, with a quartz/barite gangue. The commercially valuable constituents consist of sphalerite, predominant over galena, together with minor proportions of chalcopyrite.

The pyrite occurs as homogenous equant grains, up to 1mm or so in size. Occasionally these show adhering selvedges (or rare inclusions) of galena, sphalerite or chalcopyrite, or are simple composites with intergrowths of these constituents, or gangue. The valuable constituents occur, to a considerable degree, as liberated grains but, in part, are mutual intergrowths (sometimes including gangue). The scale of these intergrowths ranges from fine to relatively coarse, and the general impression from this polished section is of a distinctly less fine-grained ore than that exemplified by the Faro Pits 2, 3 and 4 samples and some of the individual core samples of the suite. Fragments of essentially homogenous sphalerite up to 0.5mm, and of galena up to 0.2mm, are relatively common. There are, of course, also examples of much finer intergrowths, down to 20 microns or so, but the overall impression is that a grind to -200 mesh would result in good liberation.

Minor accessories are pyrrhotite and fine-grained secondary-type pyrite and/or marcasite (probably derived from original pyrrhotite). These mostly occur as discrete segregations, though pyrrhotite is occasionally seen in fine-grained intergrowth with sphalerite and/or chalcopyrite.

All components appear fresh.

...

**HEAD SAMPLE: FARO PIT 2**

Estimated mode

| | |
|---|---|
| Pyrite | 32 |
| Magnetite | 6 |
| Sphalerite | 11 |
| Chalcopyrite | trace |
| Galena | 6 |
| Pyrrhotite | 2 |
| Marcasite | 1 |
| Barite | 25 |
| Carbonate | 2 |
| Quartz | 15 |

The overall composition of this ore (as represented by the material of the polished section) is less pyritic and richer in barite/ quartz gangue than that exemplified by the Pit 1 sample. It also differs in having a relatively higher content of galena, and in containing substantial amounts of accessory magnetite.

However, the most striking difference from the Pit 1 sample is the predominantly much finer scale of textural intergrowth exhibited by the constituents.

Pyrite grain size ranges from 20 - 300 microns. It typically occurs as individual subhedral grains, disseminated though a matrix of intimately intergrown sphalerite, gangue, galena, magnetite and pyrrhotite (in various proportions). It also forms semi-massive aggregates intergrown with gangue, sometimes having small pockets of the valuable constituents.

Sphalerite is seen as segregated pockets up to about 200 microns or more in size, but galena areas seldom exceed 100 microns. For the most part both minerals show a considerably finer scale of intergrowth than this, in the range 5 - 80 microns.

The fine intergrowths are mainly of galena and sphalerite, sometimes with gangue, or more rarely pyrrhotite, as a third or fourth component.

Magnetite is relatively abundant, as small granules in sphalerite and as aggregated clumps with tiny inclusions of sphalerite and galena.

Chalcopyrite is very rare.

Ore of this type will require very fine grinding to achieve satisfactory liberation (see photomicrographs).

All components appear fresh.

**HEAD SAMPLE: FARO PIT 3**

Estimated mode

| | |
|---|---|
| Pyrite | 52 |
| Sphalerite | 7 |
| Galena | 3.5 |
| Pyrrhotite | 2.5 |
| Magnetite | 0.5 |
| Arsenopyrite | 0.5 |
| Chalcopyrite | 0.5 |
| Altered galena | trace |
| Digenite) Covellite) | trace |
| Quartz | 18 |
| Barite | 15 |
| Sericite | 0.5 |
| Carbonate | 2 |

This ore type is generally similar to the previous samples. The overall galena content is comparable with that of the Pit 1 sample, and the given assay seems high by comparison. Texturally the intergrowths are similar to the Pit 2 sample, with a few fragments of generally coarser texture, similar to the Pit 1 material.

Pyrite forms individual subhedral grains, 20 - 500 microns in size. It also occurs as compact granular aggregates which are largely free of other sulfides, except for minor flecks and intergranular threads of chalcopyrite and/or galena. For the most part, the pyrite individuals occur more or less densely disseminated through a matrix of gangue with sporadic pockets of galena and sphalerite. Occasional fragments are seen in which the matrix consists of Pb-Zn sulfides with minimal gangue.

Chalcopyrite is noticeably more abundant in this sample than most of the others (though still minor overall). It occurs as sporadic interstitial pockets in aggregated pyrite, and as occasional ragged patches in gangue.

Some coarse fragments of pyrrhotite (partly showing colloform alteration to secondary pyrite/marcasite) are present, and the overall proportion of this constituent is higher than in the other pit samples. Occasional grains of arsenopyrite are intergrown with the pyrite aggregates. Magnetite is much rarer than in the Pit 2 sample.

This sample shows incipient development of the alteration effects which are more strongly displayed in the Pit 4 material and in drill core samples V90 PL-01, 60044 and 60047. A very small proportion of the galena shows diffuse, dusty to crustified, rim-type alteration, and the sample includes occasional small, random patches of bluish secondary Cu sulfides. The latter are generally associated with sphalerite or gangue rather than chalcopyrite (which is typically fresh).

**HEAD SAMPLE: FARO PIT 4**

Estimated mode

| | |
|---|---|
| Pyrite | 39 |
| Sphalerite | 3 |
| Galena) | 10.5 |
| Altered galena) | |
| Chalcopyrite | trace |
| Secondary Cu sulfides | trace |
| Quartz | 20 |
| Barite | 27 |
| Carbonate | 0.5 |

This ore-type, though of similar basic mineralogy to the other pit samples, shows distinctive features. The ratio of galena to sphalerite is notably high (at least as regards the material making up the polished section); the pyrite partly shows a distinctive fractured/fragmented texture, and locally appears to be replaced by the galena; and the galena shows rather extensive alteration.

Pyrite shows a very wide grain size, from individual subhedra up to 1cm or more in size (homogenous but for a few small galena inclusions or veinlets) down to swarms of minute remnants, 2 - 10 microns in size, in matrices of galena or altered galena. Clumps of compact granular aggregates of pyrite are also seen.

Pyrite grains can be observed in all stages of fragmentation, veining/cementation and assimilation by galena. The latter shows varying degrees of alteration to unidentified non-reflective secondary products.

The textural diversity of galena alteration process is best appreciated by reference to the photomicrographs. The galena ranges from apparently fresh and normal, through a mildly dusty and mottled appearance (incipient alteration), to more strongly altered variants consisting of specks and lattice works of remnant galena in a matrix of non-reflective secondary material. A final stage of complete destruction of the galena yields more or less extensive patches of the secondary products (often difficult to differentiate from the primary gangue components).

Sometimes the secondary products, and/or a remobilized form of galena, appear to penetrate adjacent sphalerite - commonly with the development of intergranular films and diffuse patches of associated bluish secondary Cu sulfides. The latter are only rarely seen in direct association with chalcopyrite, which is a sporadic trace component of the primary polyphase intergrowth (though notably less abundant than in the Pit 3 sample). Rather, they seem to have developed by mobilization and reconstitution of Cu held in solid solution (or micron-sized exsolved blebs) in the sphalerite.

The surface properties of the galena and, to some degree, the sphalerite in this material will have been more or less profoundly

modified by the alteration, leading to non-standard behaviour of this ore type in flotation.

Certain puzzling inconsistencies exist which bear on the conditions and processes which have caused the development of this distinctive ore type. It is beyond the scope of the present study to pursue these in detail, but they present an interesting geological puzzle. For instance, are the physical breadown (microbrecciation) of pyrite and its apparent replacement by galena in some way related to the prevalence of secondary processes in this sample? Could the galena itself be partly secondary or redistributed? If the galena alteration is a conventional surface-related weathering/oxidation phenomenon, why does the pyrite show no limonitization? (and why are the Cu-enriched sulfides, like covellite and digenite, developed rather than oxidized species like malachite?).

**Pb CONCENTRATE 1**

Estimated mode

| | |
|---|---|
| Galena | 76 |
| Sphalerite | 11.5 |
| Pyrite | 10 |
| Chalcopyrite | 0.5 |
| Pyrrhotite | trace |
| Gangue | 2 |

This product has a predominant particle size range of 2 - 40 microns, plus scattered, coarser grains to 70 microns.

Galena is the principal constituent, with sphalerite and pyrite the chief impurities. The non-sulfide content is notably low.

The majority of the pyrite appears free. An estimated 20% of the pyrite grains have small corners or selvedges of galena.

By comparison, a much higher proportion (50 - 60%) of the sphalerite grains show "corners" of galena, or are simple composites.

Of the minor constituents, chalcopyrite resembles the pyrite in its locking characteristics (mainly free), whilst the gangue is more like the sphalerite (often with intergrown galena).

The scale of the pyrite/galena and sphalerite/galena locking is in the range 2 - 20 microns. 3-phase locking of these components is notably rare.

**Pb CONCENTRATE 2**

Estimated mode

| | |
|---|---|
| Sphalerite | 56 |
| Galena) | 9 |
| Altered galena) | |
| Pyrite | 7 |
| Chalcopyrite | 0.5 |
| Secondary Cu sulfides | 1 |
| Gangue | 26.5 |

This is a very finely ground product, almost entirely in the particle size range of 1 - 35 microns. Very rare coarser grains, in the range 50 - 100 microns, are also seen.

Its composition is notably different from that of Pb Concentrate 1, in that the ratio of galena to sphalerite is virtually reversed. Also, it has a much higher content of gangue (non-sulfide) material.

The observed mineralogical proportions appear somewhat at odds with the given assay, the preponderance of sphalerite and paucity of galena being even more pronounced than the assay data would suggest.

Apart from their overall smaller average size, the galena and pyrite grains in this sample are similar to those in Concentrate 1, being predominantly liberated, angular particles.

The sphalerite shows a much lower degree of locking with galena than in the previous sample, an estimated 90 - 95% of the sphalerite particles apparently being free. The same is true of the gangue.

Other important differences from Pb Concentrate 1 are observable. A proportion of the sphalerite particles show thin, partial to complete rims of apparent galena. Details of this feature are not easy to see, nor is its overall frequency easily estimated, owing to the small size of the grains and the extreme thinness of the coatings. Certainly a proportion of the "free" sphalerite particles are, in fact, of this type. The photomicrographs provide a useful illustration. This feature is probably a manifestation of that observed in V90 PL-1, where films of "altered galena" are seen penetrating sphalerite grain boundaries and contacts.

In addition, a proportion of the galena particles are of more or less altered type, being of porous or minutely microgranular appearance and/or being dusted with low-reflective secondary products.

Another distinctive feature is the presence of a minor proportion of bluish, secondary Cu sulfides (probably mixtures of covellite/digenit and chalcocite). This material occurs in the concentrate as tiny, irregular granules or cryptocrystalline aggregates, often in intimate intergrowth with galena - probably of altered or secondary

type. It is also occasionally seen as a component of the galena-like coatings on sphalerite (see photomicrographs). Interestingly, the majority of the chalcopyrite grains in the concentrate are liberated particles free of apparent surface alteration effects.

**Pb TAILINGS 1**

Estimated mode

| | |
|---|---|
| Pyrite | 44 |
| Pyrrhotite) Marcasite) | 1.5 |
| Sphalerite | 5.5 |
| Magnetite | 1 |
| Chalcopyrite | trace |
| Galena | trace |
| Quartz | 16 |
| Barite | 12 |
| Carbonate | 20 |

This product has a particle size range of 5 - 100 microns. The polished section consists of patches of flocculated fines (particles 2 - 30 microns in size) alternating with dispersed material of coarser average size (range 5 - 100 microns).

Pyrite and gangue are the predominant constituents. The pyrite is almost totally (~98%) liberated. Occasional grains have small corners or inclusions of sphalerite. The gangue (a mixture of quartz, barite and carbonate) is also mostly liberated. About 5% of the gangue particles show minor intergrown specks of sphalerite.

Sphalerite, the main accessory component, also shows a generally high degree of liberation. A maximum of 10% of the sphalerite is locked as composites with gangue or pyrite.

The predominantly liberated state of the sphalerite in this product suggests that it should be readily recoverable in the Zn flotation stage.

Galena is strikingly rare in this product, attesting to excellent Pb recovery. The virtual absence of included galena specks in sphalerite or pyrite grains is remarkable. The observed abundance of galena in the mounted portion of this sample appears considerably less than is indicated by the given assay (0.54% Pb).

**Pb TAILINGS 2**

Estimated mode

| | |
|---|---|
| Pyrite | 45 |
| Sphalerite | 12 |
| Galena | 1.5 |
| Chalcopyrite | trace |
| Arsenopyrite | trace |
| Altered galena | 1 |
| Secondary Cu sulfides | trace |
| Quartz | 18 |
| Barite | 22 |
| Carbonate | 0.5 |

This product has a wide particle size range. Material in the lower part of the size range (2 - 30 microns) occurs as sharply-defined flocculated clumps in the slide, separated by dispersed grains of coarser average size (range 20 - 125 microns). The mineralogical ratios are perceptibly different in these two types of material, with a much higher proportion of pyrite vs sphalerite in the coarser size range.

Compared with the optically estimated mineralogical proportions, the given assay appears low in Fe and high in Pb.

The general composition is similar to that of Pb Tailings 1, pyrite and gangue being the two principal components. Note, however, that the gangue in this sample differs in containing very little carbonate.

Both pyrite and gangue are predominantly as free particles. The extremely high percentage liberation of gangue (estimated as c.99%; i.e. perfect, but for rare, tiny inclusions of sphalerite in a few gangue particles) is somewhat surprising. Pyrite, by comparison, shows a noticeably higher degree of locking than in Tailings 1, chiefly as a result of its larger average particle size. Approximately 20% of the pyrite grains (chiefly the larger ones) have small corners or selvedges of sphalerite or, less commonly, galena.

Sphalerite shows a distinctly higher average abundance in this product than in Pb Tailings 1. Approximately 20% of the sphalerite in the coarser size fraction is locked, occurring as corners and inclusions in pyrite grains, and as composites with intergrown galena. Liberation in the fine size ranges is more complete.

Galena is notably more abundant than in Pb Tailings 1, indicating relatively poorer recovery in the Pb flotation stage. This is confirmed by the low galena content of the corresponding concentrate (q.v.). An estimated 50% of the galena occurs as liberated particles, the remainder being locked with pyrite and sphalerite - mainly in the coarser size ranges.

A proportion of the galena grains (both free and locked) have a more or less dusty or porous/microgranular appearance, and probably represent an altered or secondary form. This material often appears to include various proportions of intimately intergrown secondary Cu sulfides.

The secondary-type galena (and/or Cu sulfides) is also seen as thin coatings to sphalerite grains. The presence of such particles in this product indicates that the rimming feature does not consistently cause the premature floating of sphalerite so affected. In fact, the presence of significant proportions of free grains of the secondary or altered-type galena in the present product would suggest that it is relatively reluctant to float (as indicated by the low Pb content of the corresponding concentrate).

Chalcopyrite is slightly more abundant in this product than in Pb Tailings 1, though still of very low abundance (c.0.1%). It occurs as free grains and simple composites (with galena or sphalerite), most of which appear fresh - though some have micron or sub-micron coatings of secondary sulfides.

**ROCK SAMPLE V90 DT-12**

Estimated mode

| | |
|---|---|
| Pyrite | 30 |
| Sphalerite | 18 |
| Galena | 5 |
| Magnetite | 1 |
| Chalcopyrite | trace |
| Quartz | 20 |
| Barite | 16 |
| Carbonate | 10 |

This sample consists of disseminated, fine-grained pyrite, in a quartz-barite matrix with intimately intergrown sphalerite and galena. A weak, irregular, laminar texture is defined by thin wisps or trains of more concentrated pyrite. One side of the sectioned portion shows a gradation to a lensy concentration of semi-massive sulfides.

In thin section the matrix in the disseminated sulfide portion is found to exhibit a pseudo-clastic texture of individual sub-angular to sub-rounded grains of barite and lesser quartz, 0.1 - 0.6mm in size, set in a minutely granular to cherty groundmass of quartz, of grain size 5 - 50 microns. Carbonate is a minor accessory, as random flecks and granules.

Marginal to and within the more massive sulfide area, carbonate becomes the dominant gangue component.

The pyrite occurs as disseminated, individual, equant/subhedral grains, 30 - 500 microns in size. In the more massive portion these are in partial contact. Pyrite grain outlines are typically minutely embayed by the fine-grained quartz and Pb/Zn sulfides of the matrix. Some pyrite grains have small, rounded to angular inclusions of sphalerite or, more rarely, galena.

The Pb/Zn sulfides occur as an intimate impregnation of the cherty groundmass component of the matrix. Much of this intergrowth of galena, sphalerite and quartz is extremely fine (in the 2 - 30 micron range) and is unlikely to be fully liberated at a practicable grind. This is particularly true of the galena, which is a relatively minor component compared to sphalerite, in the sectioned portion of this sample. It shows a maximum grain size of about 50 microns.

The sphalerite, by comparison, shows pockety segregations (pure but for minor included specks of galena and gangue) up to 150 microns or more.

Magnetite is a minor accessory, as occasional small granules or aggregated clumps, generally within sphalerite.

Rock Sample V90 DT-12 cont.

Chalcopyrite is extremely rare in this sample, being confined to a couple of small areas of tiny specks associated with carbonate gangue. It is not seen as an exsolved component of the sphalerite in this sample. The lack of pyrrhotite is another notable feature.

The sulfides are fresh throughout.

**ROCK SAMPLE V90 PL-01**

Estimated mode

| | |
|---|---|
| Pyrite | 32 |
| Sphalerite | 21 |
| Galena | 8 |
| Altered galena | 3.5 |
| Chalcopyrite | trace |
| Secondary Cu sulfides | 0.5 |
| Barite | 23 |
| Quartz | 7 |
| Carbonate | 5 |

This sample resembles DT-12 in its general macroscopic character, being a more or less dense dissemination of individual pyrite grains in a matrix of gangue and Pb-Zn sulfides. The pyrite grains locally aggregate to form gradational semi-massive patches.

In thin section the primary mineralogy is found to be simple and very similar to that of DT-12, though the present sample is significantly coarser grained.

The principal difference - and the probable cause of the aberrant behaviour of this material in the mill - is an intimate intergranular/ pervasive development of secondary alteration in the galena and sphalerite. The sample shows a slight local vugginess on the macro-scale.

The pyrite forms notably ragged-margined, equant individuals, 50 - 700 microns in size. These are homogenous (apart from occasional tiny inclusions of sphalerite and galena) and fresh in appearance, with no recognizable development of limonite.

The matrix consists of an aggregate of equant to stumpy prismatic grains of barite, with minor quartz and carbonate, of grain size 20 - 500 microns. The barite and quartz aggregate is intimately permeated, in cementing mode, by intergrown sphalerite and galena. The scale of intergrowth of gangue and Pb-Zn sulfides ranges from about 10 microns to relatively coarse, pockety segregations of sphalerite (and, less commonly, galena) up to 200 or 300 microns.

The alteration takes the form of a grey, low-reflective secondary mineral developing in the pockets of galena as diffuse to micro-colloform/crustified rim textures and patches. It most commonly develops from the edges of galena areas (in contact with sphalerite or gangue) and works inwards, in some cases totally replacing areas up to 100 or 200 microns in size.

Locally the alteration product grades to a more or less strong blue colour, resembling the secondary Cu sulfides chalcocite and/or digenite. Although very rare tiny grains of chalcopyrite are recognizable, the development of the blue (as opposed to the grey) alteration does not appear spatially related to them.

The alteration, though typically originating in the galena, also sometimes extends as thread-like veinlets into the adjacent sphalerite, and forms extremely thin (~1 micron) films along sphalerite/gangue contacts (see photomicrographs). The material of these films appears to have a reflectivity similar to that of normal galena rather than an oxidized derivative.

Although the total abundance of the alteration products is not high, its distribution tends to be pervasive throughout the mineral aggregate, and could well have a profound effect on the surface properties of the comminuted ore.

**SAMPLE 60044**

Estimated mode

| | |
|---|---|
| Pyrite | 15 |
| Sphalerite | 5 |
| Galena | 4 |
| Altered galena | 9 |
| Chalcopyrite | trace |
| Secondary Cu sulfides | trace |
| Quartz | 7 |
| Barite | 60 |

This sample consists of relatively sparsely disseminated pyrite in a matrix of gangue with rather irregular, pockety concentrations of galena. The distribution of pyrite, as trains of individual grains, defines a crude laminar texture on the macro-scale. The sample shows a noticeable vuggy porosity.

Grain size of the gangue matrix is predominantly in the range 50 - 300 microns, with barite mainly forming relatively coarser, equant/ sub-prismatic grains, abundantly scattered through a somewhat finer mosaic which is relatively richer in quartz. Carbonate is absent from the sectioned portion.

Pyrite forms scattered disseminated subhedra, 50 - 500 microns in size. The pyrite grains in this sample are distinctive in being strongly shattered. It is sometimes recognizably replaced by galena or secondary products via networks of microfractures, and, in extreme cases, reduced to clusters of angular remnants in a galena matrix.

The proportion of sphalerite to galena is much lower than in the other samples of the suite. The sphalerite occurs as pockets up to 150 microns in size, and as clusters of tiny granules within galena or altered galena. The sphalerite often appears fragmented, and more or less leached out and replaced by secondary products along grain boundaries and microfractures.

Galena in this sample occurs intergrown with sphalerite as an interstitial permeation of the gangue matrix. It is relatively abundant, and forms some pockets up to 300 microns or more in size. It sometimes shows active replacement of sphalerite and pyrite which occur within the galena as clusters of tiny remnants.

The galena is extensively and diffusely altered to low-reflective secondary products, sometimes packed with minute lattice-works and granules of relict galena. The same, or related secondary material, partially replaces the adjacent sphalerite.

Chalcopyrite is seen as extremely rare tiny specks. The blue secondary Cu sulfides (relatively prominent in V90 PL-01) are likewise extremely rare.

This ore type is severely modified by alteration and leaching.

**SAMPLE 60047**

Estimated mode

| | |
|---|---|
| Pyrite | 70 |
| Galena | 7 |
| Sphalerite | 15 |
| Chalcopyrite | 0.5 |
| Arsenopyrite | trace |
| Pyrrhotite | trace |
| Altered galena | 7 |
| Quartz | trace |

The sectioned portion of this sample is a fine-grained massive sulfide, lacking the laminar fabric apparent in most of the other samples of the suite. It is noticeably vuggy and porous (see sut-off block).

In thin section the extreme paucity of gangue is a striking feature. Rare flecks of fine-grained quartz are recognizable but, overall, the sample consists almost entirely of massive sulfides. The pore spaces are typically coated with secondary Pg/Zn minerals, and probably result from the partial leaching of the latter.

Pyrite is the principal constituent, occurring as equant, subhedral individuals, 20 - 400 microns in size. These are densely and rather evenly disseminated (but only rarely in contact) through a matrix of galena and sphalerite.

Trace accessories are arsenopyrite (as rare individual grains intergrown with, and of comparable size to, the pyrite) and pyrrhotite as occasional tiny flecks interstitial to the pyrite.

Chalcopyrite is relatively prominent compared with most of the samples of the suite, though quantitavely minor. It occurs sporadically within the matrix assemblage as small flecks intergrown with galena and sphalerite, concentrating as a few patches where it cements - and occasionally fills fractures - in pyrite grains.

The scale of intergrowth of galena and sphalerite interstitial to the pyrite is mainly in the range 5 - 100 microns.

Much of the galena shows alteration, ranging from a dusty, tarnished appearance to conversion to a totally non-polishable material (apparently soft, and often leached or plucked out) incorporating minute specks and lattice works of relict galena. The sphalerite and the pyrite do not seem to show alteration of a specific type (e.g. to limonite or smithsonite), but they locally appear to be replaced by the altered Pb phase.

The complete freshness of the pyrite, in comparison to the extensively altered nature of the galena, is a puzzling feature. Chalcopyrite, likewise, is apparently unaffected, even in immediate proximity to strongly altered galena.

**SAMPLE 60051**

Estimated mode

| | |
|---|---|
| Pyrite | 60 |
| Pyrrhotite | 2 |
| Marcasite | 6 |
| Sphalerite | 5 |
| Chalcopyrite | 1 |
| Magnetite | 5 |
| Galena | 6 |
| Arsenopyrite | trace |
| Carbonate | 15 |

Macroscopically this sample is a rather featureless, fine-grained, pyrite-rich massive sulfide. It includes a few diffuse, sub-parallel lenses or bands of sulfide-poor material.

In the polished thin section it is found to consist essentially of a more or less closely-packed aggregate of cubic/subhedral grains of pyrite, 25 - 400 microns in size.

The gangue in the sectioned portion is distinctive in that it consists entirely of carbonate (unreactive to dilute acid, and probably dolomite or ankerite). This forms a semi-continuous interstitial network throughout the pyrite aggregate, and is the dominant constituent in the sporadic, sulfide-poor streaks and patches.

Sphalerite, galena and chalcopyrite are minor accessories, occurring (individually or intergrown with one another and/or with carbonate) as intergranular threads and tiny angular pockets in the pyrite. Their grain size, in this association, is mainly in the range of 5 - 50 microns.

Sulfides also occur as disseminated clusters and irregular pockets in the carbonate segregations. Pyrrhotite and magnetite are notable constituents in this context, whilst sphalerite and galena partly form substantially coarser clumps (grain size 100 - 200 microns) than in the pyrite matrix. Chalcopyrite is notably absent in the carbonate-rich areas.

The principal interstitial/cementing phase in the pyrite adjacent to the carbonate segregations is marcasite - probably secondary after pyrrhotite. Marcasite also occurs (though less prominently) as a minor interstitial accessory throughout the pyrite aggregate.

This sample lacks the alteration of chalcopyrite, galena and sphalerite distinguishing the previous two samples (60044 and 47), and appears totally fresh. The overall concentrations of galena and sphalerite are relatively low, but the textural intergrowths (though partly fine-grained) appear relatively simple, and this ore type should not present particular problems in treatment.

**SAMPLE 60053**

Estimated mode

| | |
|---|---|
| Pyrite | 72 |
| Galena | 7 |
| Sphalerite | 5.5 |
| Chalcopyrite | 0.5 |
| Carbonate | 14 |
| Sericite) Biotite) | 1 |

This material is of similar general macroscopic appearance to 60051, except that - in the sectioned portion - it lacks the segregated sulfide-poor streaks and patches of the previous sample.

Polished thin section observations indicate additional differences in that pyrrhotite, marcasite and magnetite are all absent.

The gangue is, as in 60051, entirely carbonate, locally showing pockets of rather coarse sparry habit. It includes diffuse wisps and patches of a minutely felted, brownish material which may be a form of sericite or secondary biotite.

Pyrite is the predominant constituent, as an aggregate of cubic, euhedral to subhedral grains, 10 - 350 microns in size. In part, the pyrite coalesces to form compact masses, but mainly the angular interstices between pyrite grains are filled by carbonate and/or accessory sulfides. Locally the pyrite grains show crenulated outlines, apparently representing cementation by overgrowths of minutely fine-grained pyrite, often with incorporated specks of galena, 1 - 10 microns in size.

As in Sample 60051, galena and sphalerite (and occasionally chalcopyrite) occur as intergranular threads and pockets in the pyrite aggregate, having an effective grain size in the range 10 - 50 microns. There are also occasional coarser segregations of 50 - 200 microns. The sphalerite in this sample is distinctive in that it is consistently speckled with minute exsolved specks of chalcopyrite.

Local segregated patches of pyrite-free carbonate generally include irregular intergrowths of galena, chalcopyrite and sphalerite - of a similar grain size to that in the pyritic matrix.

The sulfides are all fresh, and this material should show similar treatment characteristics to 60051. Compared with the assay for the whole interval from 62.2 - 67.1 ft., the sectioned portion appears atypically rich in galena and sphalerite.

**SAMPLE 60418**

Estimated mode

| | |
|---|---|
| Pyrrhotite | 23 |
| Secondary pyrite | 28 |
| Marcasite | 3 |
| Pyrite | 1 |
| Sphalerite | 8 |
| Magnetite | 2 |
| Galena | 5 |
| Chalcopyrite | trace |
| Carbonate | 30 |
| Quartz | trace |

This sample consists of fine-grained, massive sulfide in which the gangue component appears, in part, to be in the form of sub-rounded, clast-like bodies (see cut-off block).

The polished thin section shows that the sample is of distinctive mineralogy, being virtually devoid of the euhedral pyrite component which is prominent in the rest of the suite. Instead, it is composed essentially of pyrrhotite and a secondary form of pyrite, - clearly derived by alteration of pyrrhotite.

The gangue is almost entirely carbonate, as an anhedral aggregate of grain size 10 - 150 microns. Part of the sectioned portion is somewhat porous. This appears to reflect a vugginess in the carbonate, with open pores lined by coatings of minutely granular crystals. There are scattered small grains of quartz, possibly as a partial filling of the carbonate vugs.

Pyrrhotite, as mosaic aggregates of grain size 30 - 150 microns, forms clumps and ramifying networks in complex intergrowth with carbonate. The latter occurs as rounded inclusions incorporated within massive pyrrhotite, and as more or less discrete, rounded pods (the clast-like bodies), up to 1 or 2mm in size.

The pyrrhotite shows extensive alteration to minutely fine-grained, brownish, "dusty-looking" secondary-type pyrite, which pseudomorphs the grain fabric of the pyrrhotite, or forms cellular networks defined by the pyrrhotite grain boundaries. Locally the pyrrhotite shows alteration to porous, platy-textured growths of fine-grained marcasite. Occasional cubes of primary-type pyrite occur within the pyrrhotite aggregate or its altered form.

The accessory sulfides (galena and sphalerite) occur mainly in intimate intergrowth with the carbonate patches. Some pyrrhotite/ secondary pyrite and magnetite are also part of this association. The resultant multi-component intergrowths are on a scale ranging from 0.2mm down to a few microns. The galena (and minor chalcopyrite, where seen) shows no sign of alteration, and this ore type should be treatable, insofar as liberation can be achieved.

**SAMPLE 60419**

Estimated mode

| | |
|---|---|
| Pyrite | 35 |
| Marcasite | 1 |
| Magnetite | 2 |
| Sphalerite | 16 |
| Galena | 7 |
| Chalcopyrite | trace |
| Quartz | 37 |
| Carbonate | 2 |
| Barite | trace |

This is a finely laminated ore type, consisting of thin, parallel zones distinguished by varying ratios of sulfides to quartz.

Pyrite is the predominant constituent, as individual, cubic euhedral-subhedral grains, 0.03 - 0.5mm in size. Quartz is the other major component, intergrown with the pyrite as fine-grained mosaic aggregates and coarser individual anhedra, in the same grain size range as the pyrite. The latter contain abundant fluid inclusions, up to 25 microns in size, often with active vapour bubbles.

Sphalerite and galena intimately permeate the quartz, locally acting as a matrix to the coarser quartz individuals. The pyrite cubes sometimes show slight marginal embayment (replacement?) by the Pb-Zn sulfides, which also (especially sphalerite) form rounded, bleb-like to angular inclusions, 10 - 100 microns in size, within some pyrite grains.

Sphalerite is notably more abundant than galena in the sectioned portion of this sample. Its intergrowths include segregations in the range 10 - 200 microns, with a substantial proportion in the upper part of this size range. Galena is less abundant and generally finer grained, it seldom exceeding 50 microns.

Accessory components include marcasite, as local concentrations of lamellar-textured grains (probably secondary after pyrrhotite) intergrown with gangue and sphalerite - particularly in a few laminar zones in which carbonate is the predominant gangue. Magnetite is another accessory, as sporadic, irregular patches and granular clusters, generally intergrown with sphalerite.

Chalcopyrite is confined to one or two individual laminae, composed essentially of quartz with only very minor sulfides. It forms small interstitial flecks, 10 -50 microns in size.

Sulfides in this sample are fresh, and should be amenable to concentration.

Sample 60419 cont.

Note that the sectioned portion contains essentially no barite. This is inconsistent with the assay of 8.3% BaO (for the 4' interval from which the sample came), and with the logged description of this interval as "massive baritic ore". This discrepancy presumably results from the small-scale variability characteristic of deposits of this type.

**SAMPLE 60421**

Estimated mode

| | |
|---|---|
| Pyrite | 40 |
| Sphalerite | 11 |
| Galena | 9 |
| Chalcopyrite | trace |
| Barite | 14 |
| Quartz | 14 |
| Carbonate | 12 |
| Sericite | trace |

The sectioned portion of this sample shows a weakly laminated fabric of rather evenly disseminated, fine-grained sulfides in gangue. This is disrupted by discordant veinlets of a cream-coloured mineral.

Thin section examination show that the gangue component consists of an intergrowth of quartz, barite and carbonate, predominantly as a weakly-oriented anhedral aggregate, of grain size 20 - 200 microns. The discordant veining is composed of carbonate with pockets of quartz and coarse, sparry barite, as grains 0.2 - 1.0mm in size. A little fine-grained sericite is intergrown with the vein carbonate.

Pyrite is the most abundant sulfide, exhibiting similar general textural form to that in the other samples. It occurs as euhedral-subhedral, cubic individuals, more or less densely disseminated through a matrix of intimately intergrown gangue and Pb-Zn sulfides. The pyrite grains often show marginal embayment by, and sometimes contain inclusions of, the galena and sphalerite.

The majority of the pyrite is in the grain size range 40 - 400 microns. Local development of finer-grained pyrite, down to 10 microns or less is also seen. This occurs in intimate intergrowth with galena and sphalerite, as an interstitial phase to the rather rounded, crenulate-margined pyrite individuals of larger size. Even the finest practicable grind will be ineffective in liberating the valuable components in this interstitial assemblage.

For the most part the intergrowth is somewhat coarser and comparable to that in the other samples. Sphalerite shows a grain size of 10 - 250 microns, whilst galena is somewhat finer - seldom exceeding 100 microns. The coarser sphalerite patches in this sample are distinctive in being evenly dusted with micron-sized ex-solution specks of chalcopyrite.

Chalcopyrite also occurs as a few localized zones where it forms disseminations and small pockets in sulfide-poor gangue patches and in carbonate veinlets.

The sulfides appear fresh and normal in this sample, and such material should be amenable to separation by flotation - except for that portion which cannot be fully liberated by grinding.

**SAMPLE 60423**

Estimated mode

| | |
|---|---|
| Pyrite | 53 |
| Sphalerite | 3 |
| Chalcopyrite | trace |
| Galena | trace |
| Carbonate | 12 |
| Quartz | 28 |
| Sericite/Talc | 1 |
| Clays? | 3 |

The sectioned portion of this sample consists of fine-grained, incipiently-banded massive pyrite, in conformable(?) contact with a sulfide-poor, siliceous zone.

The latter makes up about 30% of the slide. It consists essentially of an anhedral, somewhat crenulate-margined aggregate of quartz, of grain size 20 - 150 microns. This is host to sporadic pockets, wisps and networks of brown, micritic carbonate, felted sericite, and a low birefringent, aggregate-textured material which may be a form of clay or chlorite. Occasional zones of disseminated pyrite cubes with associated and/or included traces of chalcopyrite, galena and sphalerite also occur in this area.

The massive sulfide portion consists predominantly of pyrite, as partially coalescent/compact aggregates of equant subhedral grains, 20 - 150 microns in size. Local coarser grains of pyrite, up to as much as 800 microns, are also seen.

The pyrite is associated with a matrix/interstitial phase of intergrown quartz and carbonate, with minor pockets of the clay-like component. At one end of the slide gangue is again predominant - in this case a band of carbonate with only minor intergrown small granules of quartz.

Pb-Zn sulfides are very sparse in this sample. Sphalerite forms occasional small clusters of interstitial pockets (10 - 100 microns in size) in the massive pyrite. It also occurs - in slightly greater abundance and with associated chalcopyrite - as irregular permeations (including patches up to 200 microns in size) in the marginal zones of the pyrite-free gangue bands.

Galena is essentially absent in the sectioned portion of this sample, and material of this type would not, in itself, constitute ore.