UNITED STATES
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PROJECT REPORT
Mexico Investigations
(IR)MEX-1

A MINERALOGICAL STUDY OF THE GUANAJUATO, MEXICO SILVER-GOLD ORES

U. S. Geological Survey
OPEN FILE REPORT 75-70
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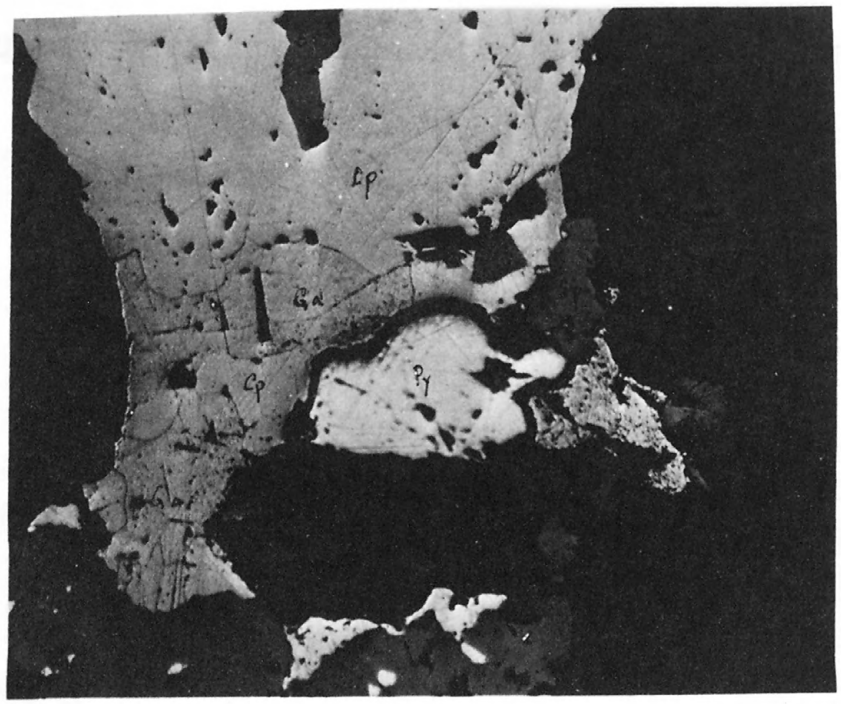
Ivan F. Wilson, Charles Milton, and J. R. Houston



W50 - 6 X150 (Polished section 601)

Pyrite (Py), Sphalerite (Sp), Chalcopyrite (Cp), Galena (Ga).

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
GEOCHEMISTRY AND PETROLOGY

Report No. IWM-269
Job 584

For Ivan F. Wilson
(Letter dated August 7, 1950 and
supplemental letter dated September 11, 1950)

A Mineralogical Study of the Guanajuato, Mexico Silver-gold ores

by

Ivan F. Wilson, Charles Milton, and J. R. Houston

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By

Reported-Date

U. S. GOVERNMENT PRINTING OFFICE 16—56852-2

Branch of Geochemistry and Petrology.

A Mineralogical Study of the Guanajuato, Mexico, Silver-Gold Ores.*

by

Ivan F. Wilson, Charles Milton, J. R. Houston

Abstract

The silver-gold ores now being worked in the Guanajuato, Mexico, mining district consist chiefly of argentite and native gold-silver, with minor amounts of polybasite, pyrargyrite, and some argyrodite, a silver germanium sulfide. With these are always associated galena, sphalerite, chalcopyrite, pyrite, and minor amounts of marcasite. The gangue is generally a breccia of various rock types, mostly volcanics, cemented by calcite that has been largely replaced by quartz. The quartz is often amethystine, and is the carrier of the metallic minerals. The breccia fragments are pyritized, but not markedly mineralized otherwise; most of the ore minerals are in the quartzitic cementing materials; however, relatively large crystals of the complex sulphosalts appear to be younger than, i.e., deposited on, the quartz crystals in vugs.

The mineralization is not of the banded-vein type, but consists of discrete ore particles in patches and streaks in the quartz. In general there is no clear indication that any of the base-metal sulfides are in a definite age sequence; there is evidence of argentite replacing galena, as well as the other sulfides.

There are local variations in the gangue - a soapstone ("jabon") is worked locally, and also a porous leached (?) siliceous rock ("charasco"). The character of the mineralization, however, is essentially constant throughout the area studied, and in particular no significant variation was noted in the several vein systems.

Investigation of gas-liquid inclusions in the quartz suggests that the ores were deposited at about 254°C and, therefore, that the mineralization is hydrothermal.

Possible recovery of the base-metal content of the ore is considered; it is computed that several hundred thousand dollars worth of copper, zinc, and lead is mined and milled annually, and discarded as tailings and/or slag. This with similar waste from not-too remote mining districts might be processed at some central point for profitable recovery. Hitherto unrecognized germanium is also present, but in the absence of a cheap and reliable method of estimating small percentages of this metal, it is not likely that germanium can be produced economically.

A Mineralogical Study of the Guanajuato, Mexico, Silver-gold ore

INTRODUCTION

The Guanajuato mining district has been producing gold and silver for over four hundred years, valued at a half billion dollars; the district is still producing at the rate of about a thousand kg. of gold and 34,000 kg. of silver annually (1944-1945). No examination of the ore, or at least microscopic study, has been published; only general statements as to the nature of the ore can be found in the literature. For the purpose of better understanding the composition and structure of the ore minerals, a systematic collection has been made of several dozen typical ore specimens in the various mines of the district. From examination of this material, comparisons may be made with other deposits for which similar data exists, and conclusions as to paragenesis and the geological history of the mineralization drawn. Knowledge of the composition and structure of the ore also may be helpful in milling and metallurgical operations.

Description of the Guanajuato Silver-gold veins

The mines that were sampled are those now being operated by the "Cooperativa", principally the Rayas and Cata mines, both located on the famous Veta Madre of Guanajuato, which has been exploited for over 400 years. The other principal mine on the Veta Madre, the Valenciana, is no longer accessible. The Promontorio and Tiro Kurtz mines, from which some samples were collected, geologically can be considered to form part of the Rayas, although they are administered separately. To provide a general background, a brief description of the veins that were sampled will be given below. A general geologic description of Guanajuato will be found in the recent bulletin by Guiza (Mexico, Inst. Nac. Invest. Rec. Min. Bol. 22, 1949), and results of previous mineralogical studies have been published by Wandke and Martinez (Econ. Geol., v. 23, pp. 1-44, 1928). There are numerous other previous publications dealing with various phases of Guanajuato geology. ~~(a bibliography could be furnished if desired).~~

The Veta Madre is a long and wide mineralized zone following a normal fault of considerable displacement. The principal mines--Rayas, Cata, and Valenciana--extend over a length of 3 kilometers from southeast to northwest, but the fault is said to have been traced for a total length of 24 kilometers. The Rayas, Cata, and Valenciana are independent mineralized areas separated by supposedly barren areas, although the intervening ground is largely unexplored. In this stretch of the Veta Madre, the fault forms a contact between shales and phyllitesof possible Triassic age in the footwall, and "red conglomerate" of Tertiary age in the hanging wall. The conglomerate in the hanging wall has been shattered over a wide area, and it is in this zone that most of the mineralization has taken place. Much of the ore that has been mined is not found directly along the fault, but rather is in the hanging wall a considerable distance (as much as 90 meters horizontally) from the fault contact between shale and conglomerate.

The Veta Madre is a wide zone of ramifying veins and veinlets of quartz and calcite and associated minerals forming a kind of stockworks, enclosing numerous brecciated fragments and horses of wall rock (maining conglomerate). Much of the vein material carries little or no values in gold and silver, the values being concentrated only along certain parts of the zone. In places however the mined portions are very wide--as much as 30 meters horizontally. The [redacted] mine map and longitudinal section along the Veta Madre do not give a complete picture as to how much of the vein may be left, for there are large possibly mineralized areas both in the hanging wall and in the footwall of the old stopes which have not been mined and which have only partially been explored. Most of the mining at present is either in the footwall or the hanging wall of the old stopes--in some places nearly adjoining the old stopes and in other places a considerable distance away.

In the hanging wall of the Veta Madre there isa fairly well-defined pattern of branching veins, some of which are roughly parallel with the Veta Madre and others which depart from the Veta Madre at a considerable angle. These hanging wall weins are providing some of the best ore being mined at present. These veins fall in general into three sets:

1) Veins paralleling the Veta Madre, having an average strike of N. 30° - 40° W. One of the best known of these is the Santa Margarita vein, explored on the 275-meter level of Rayas.

2) Veins striking east-west to N. 70° W. Three of these veins have recently been exploited in the Rayas mine--the San Martin, San Cipriano, and Santa Cecilia veins.

3) Veins striking N. 15° - 25° W. These are less well-defined than the preceding set, but have been followed in places.

The footwall of the Veta Madre has been insufficiently explored to see whether any of the latter two sets of veins extend in that direction. It seems most likely that they are branch veins confined to the hanging wall, but that has not been absolutely proven. There are a few veins in the footwall shale paralleling the Veta Madre--one such was noted in the Cata mine, 190 level, crosscut toward Tiro Secho.

One object of the present microscopic study is to determine whether any differences are apparent in the mineralization of the various sets of veins enumerated above. For this reason samples were collected from all the principal sets of veins. The samples sent in representing each vein system are enumerated below:

Samples from Veta Madre: 1, 15, 20, 24, 27, 28, 41, 42, 43, 47, 52, 53.
Samples from Los Pozos vein (part of Veta Madre): 36, 37, 40.
Samples from Santa Margarita vein, paralleling Veta Madre: 5, 11, 44, 45.
Samples from E-W veins:
San Martin vein: 6, 13, 19.
San Cipriano vein: 8, 39.
Santa Cecilia vein: 18, 32.
Sample from N. 25° W. vein: 3.
Sample from footwall vein in shale: 29.

The sample numbers are prefixed W50 (for Wilson 1950) and run from 1 to 53. Only 31 of the samples collected have been sent to Washington for study, but all the localities sampled have been plotted on the attached map and section. To conserve space the prefix "50" has been omitted from the sample numbers on the map, so that the sample numbered W12 on the map, for example, is that listed as W50 - 12 on the attached locality list.

A series of 29 samples of wall rock from the hanging wall of the Veta Madre were collected by John Edwards in company with the writer, and will be studied for rock alteration by Edwards in connection with his studies on the "red conglomerate" of Guanajuato. ~~The localities sampled by Edwards are plotted on the accompanying map (E3, E4, etc.).~~

Previous work on Mineralogy of the ores

Wandke and Martinez/ give a general account of the district, with

/ Wandke, Alfred, and Martinez, Juan, The Guanajuato Mining District, Mexico, Economic Geology 23, pp. 1-44, 1928.

cursory reference to details of mineralogy. They give also a list of recognized minerals, cited in part and discussed below (Detailed Mineralogy of specimens W50-1). These authors refer to an earlier work by Pedro L.Monroy "Las Minas de Guanajuato, 1888", which however, can not have any microscopic-mineralogical data.

Other than Wandke and Martinez' paper, there appears to have been little written concerning the Guanajuato mineralogy. A recent bulletin

Estudio Geologico del Distrito Minero de Guanajuato Gto (Zona de la Veta Madre) Boletin Num. 22, Instituto Nacional para la Investigacion de Recursos Minerales, Reinaldo Guiza, Federico Rendon C., and J. Jesus Baltierra B. Mexico, D. F. 1949.

has only passing reference to the mineralogy.

The gist of their account follows:

"The minerals of economic importance are chiefly silver-bearing, but to a minor degree, gold-bearing, in which the gold is native as scales or cementing patches (pegaduras); in the silver-bearing ore, the silver is native in wire-form or scales, or crystallized in various compounds such as sulfides or sulfantimonides, as well as in masses of irregular form. The most frequent ratio is the Veta Madre is one part of gold to a hundred of silver, that is, to each kilogram of silver there are ten grams of gold. In certain mines the silver diminishes in ratio to the gold; the proportions may be noted in the analyses of the ores which are given in the table of production of Guanajuato (Table 8). The minerals mentioned are accompanied by others, such as galena, sphalerite, pyrite, and chalcopyrite in proportions too low for economic exploitation. Among the principal minerals making up the gangue one finds various kinds of quartz, crystallized, cellular, and amorphous; also calcite, dolomite, and the variety of adularia known as valencianite.

"In a specimen originating in the Veta Madre, taken 600 meters underground, in the Nuera Luz Mine, is a larger proportion of sulfides of lead, zinc, iron, with impoverishment in the silver-gold minerals; nevertheless, the sulfide mentioned previously (i.e. silver sulfides) are found in smaller proportions."

List of ore specimens from the Guanajuato Mining District, Guanajuato, Mexico

Samples collected from minesof the "Sociedad Cooperativa Minero Metalurgica Santa Fe de Guanajuato No. 1, S.C.L." by Ivan F. Wilson, U. S. Geological Survey, July 1950

W50 - 1. Promontorio mine, level 50, Chiflon 133 S. Part of main vein of Veta Madre. Gold and silver ore, showing prominent bands of sulfides.

W50 - 3. Rayas mine, level 275 S., Pozo 87 N., cross vein in HW of Santa Margarita, N. 25° W. Gold and silver ore, showing vuggy quartz with good sulfide crystals, also sulfides scattered thru wall rock.

W50 - 5. Rayas mine, level 275, drift 275 S., Santa Margarita vein, N. 32° W. Gold and silver ore, with prominent patches of sulfides.

W50 - 6. Rayas mine, about 18 m. below 275 level, Pozo 12 S., San Martin vein, N. 73° W. Gold and silver ore, with patches of chalcopyrite and other sulfides; also dark streaks high in silver.

W50 - 8. Rayas mine, about 5 m. below 275 level, Pozo 35 N., Frente Sur, San Cipriano (or Cuatro y medio) vein, N. 65° W. Gold and silver ore, with dark streaks of sulfides rich in silver.

W50 - 11. Rayas mine, level 255 S., Crucero alto 18 S., may be part of Santa Margarita vein. Gold and silver ore; assays high in gold; many patches of sulfides.

W50 - 13. Rayas mine, level 260, Chiflon 20 S., San Martin vein, N. 75° W. Gold and silver ore, with dark patches of sulfides high in silver. Also greenish chloritic-looking material.

W50 - 15. Rayas mine, level 230 S. Footwall portion of main vein of Veta Madre, N. 55° W. Gold and silver ore, showing dark sulfide streaks high in silver.

W50 - 18. Rayas mine, level 220 S., Rebaje 300 S., Frente Tercera Norte, Santa Cecilia vein, N. 85° W. Gold and silver ore, showing prominent dark bands of sulfides.

W50 - 19. Rayas mine, level 260 S., Chiflon 20 S., San Martin vein, N. 80° W. Gold and silver ore, with patches and bands of sulfides between quartz and wall rock.

W50 - 19A. Same locality. Crystals of argentite.

W50 - 19B. Same locality. Pyrargyrite (?).

W50 - 20. Rayas mine, San Juan region, level 220 N., part of Veta Madre. Gold and silver ore, with prominent bands of sulfides.

W50 - 24. Cata mine, level 175 S., Crucero 3 Bajo, Frente Norte. Part of Veta Madre, in footwall of old stopes. N. 60° W. Gold and silver ore, showing porous structure apparently due to leaching of calcite. This type of ore called "charrasco".

W50 - 27. Cata mine, level 190 S., Chiflon 12. Part of Veta Madre, in footwall of old stopes. N. 20° W. Gold and silver ore, showing brecciated structure, scattered sulfides, and crystals in vugs.

W50 - 27A. Same locality. Gold and silver ore, showing chalcopyrite and other sulfides.

W50 - 28. Cata mine, level 190 N., Crucero 3 Bajo. Part of Veta Madre, N. 20° W. Gold and silver ore, showing manganese oxides.

W50 - 29. Cata mine, level 190 S., Crucero Bajo 1. Vein in shale in footwall of Veta Madre; called Veta del Tiro Secho. N. 30° W. Gold and silver ore, showing prominent band of chalcopyrite adjoining amethystine quartz.

W50 - 32. Rayas mine, level 275 S., Rebaje 315 S., Chiflon 1, Santa Cecilia vein, N. 65° W. Gold and silver ore, showing vein structure--vuggy quartz enclosing fragments of wall rock.

W50 - 36. Rayas mine, level 220 S., Rebaje 14, Los Pozos vein, in HW of Veta Madre, N. 60° W. Gold and silver ore, showing dark bands of silver sulfides, cut by a later veinlet of pyrite (cross-cutting relation is very evident in mine).

W50 - 37A. Rayas mine, level 220 S., Rebaje 14, Frente Sur, Los Pozos vein, HW of Veta Madre. Porous quartz and crystalline marcasite.

W50 - 39. Rayas mine, level 275 S., Chiflon 2, San Cipriano vein, N. 85° W. Gold and silver ore, showing crystals of sulfides.

W50 - 40. Rayas mine, level 275 S., Chiflon 430 S., vein in HW of Veta Madre--possibly Los Pozos vein. Gold and silver ore, showing dark bands of sulfides paralleling quartz, also pyrite scattered thru wall rock.

W50 - 41. Cata mine, level 190 S., Chiflon 12. Part of Veta Madre, in footwall of old stopes. Gold and silver ore, showing abundant sulfides in wall rock, adjoined by veinlet of crystalline amethystine quartz.

W50 - 42. Promontorio mine, level 35, stope, coordinates 3195 S., 2038 E. Part of main vein of Veta Madre. Gold and silver ore, showing numerous dark patches of sulfides rich in silver. Assay shows 50 g. Au and 29 kilos Ag/ton.

W50 - 43. Promontorio mine, level 75 N., Frente Norte in HW. Part of main vein of Veta Madre. Gold and silver ore, showing prominent bands of sulfides.

W50 - 43A. Same locality. Gold and silver ore, showing abundant dark patches and bands of sulfides.

W50 - 44. Rayas mine, level 255 S., Crucero alto 18 A., part of Santa Margarita vein. Gold and silver ore--very high grade; assay shows 309 g. Au and 15 kilos Ag/ton.

W50 - 45. Rayas mine, level 275 N., Pozo 70 N., Santa Margarita vein, N. 35° W. Gold and silver ore, showing dark bands rich in silver; also vuggy amethystine quartz.

W50 - 47. Tiro Kurtz mine, above 55 level, Rebaje 358 N., Frente Norte. Part of Veta Madre. Gold and silver ore--soapy type called "jabon".

W50 - 52. Promontorio mine, level 50 N., Crucero 248 S., HW part of Veta Madre. Gold and silver ore, showing bands of sulfides.

W50 - 53. Promontorio mine, level 75 N., Crucero alto 260 S. Part of main vein, just below old stopes. Gold and silver ore, showing prominent dark bands of sulfides.

W50 - 54. Rayas mine, 225 level, Chiflon 11. Gold and silver ore, showing native gold. Also interesting relations of quartz veinlets.

W50 - 55*. Nuestra Senora de la Luz mine, Rancho de Alison, Hacienda de Otates, Municipio de Leon, Guanajuato. Tungsten ore containing guanajuatite and other minerals.

W50 - 56. Rayas mine. Quartz crystals, containing bubbles; sent for data on temperature of formation.

* Not included in this present study.

Identification of Guanajuato minerals

The microscopic study of a suite of ores such as the Guanajuato is beset with special difficulties, which not only must be recognized to avoid gross errors, but also to evaluate the degree of certainty of the determinative work.

For the common base sulfide minerals, pyrite, marcasite, sphalerite, chalcopyrite, and galena, no difficulty arises. These ubiquitous minerals are sharply characterized, and recognizable at a glance. A possible exception is galena, when present in very small grains, too small for the diagnostic cleavage to be evident; however, comparison with larger grains will remove any doubts as to their identity.

With the silver minerals, a different situation exists. The two important silver minerals, argentite and polybasite, are sufficiently alike in polished section to make their differentiation dependent on special criteria, requiring critical optical conditions, oil-immersion, and the like. In other words, it is impossible to glance at argentite and polybasite, in these sections at least, and be able always to say which is which. It is possible that in some instances in this report, argentite has been called polybasite, and vice versa. However, in all cases, the various factors have been weighed in identifying the mineral, and it is believed that the identifications are generally correct.

Another source of difficulty, which under more favorable working conditions would be minimized, is the photo-sensitivity of many of the silver minerals. Soon after preparation of the polished section, the silver minerals change their surface optical properties, so that they are substantially different, in various ways, from the freshly-polished surface. Fresh polishing immediately before optical study is necessary for proper work. For reasons which need not be stated here, such repolishing could not be done. For the same reasons, the sections to start with were not of the sort demanded for the highest type of work; they were of excessive relief (precluding successful photo-micrography beyond low magnifications); and improper technique resulted in numerous gouged holes, which may have contained soft silver minerals.

Another difficulty besets the proper naming of the metallic mineral present in most of the polished sections - gold, electrum, or silver. To what extent the reflected color corresponds with the gold-silver ratio is a matter of guess. A yellow color may signify high-gold content, or tarnish on high-silver. Only study of freshly-polished specimens, with a comparison-section of a series of analyzed gold-silvers, can give assurance on this point.

Of the silver minerals which had to be taken into account in this study, Table I gives the general diagnostic criteria in polished section. In many instances, X-ray analysis is necessary and conclusive, where optical methods fail.

TABLE I

DIAGNOSTIC CHARACTERS OF GUANAJUATO SILVER MINERALS IN POLISHED SECTIONS

	Color	Reflectivity	Anisotropy	Internal Reflections	Pleochroism	Light Etching	Cohesion	Special Characters	Composition
Argentite	greenish gray (against galena)		Weak	-	-	Rapid	Strongly scratched sectile	-	Ag_2S
Polybasite	pale gray-green (against galena) dull grey-white		Weak	deep red, best seen in oil	Seen in oil	Rapid	Cleavage 11(001)	-	$(Ag,Cu)_{16}(Sb,As)_2S_{11}$
Argyrolite-canfieldite	light-gray rose		Weak	-	-	Generally rapid	Strongly Scratched	-	$Ag_8(Ge,Sn)S_6$
Miargyrite	white		Strong	only clear in oil	Moderate	-	Cleavage seldom seen	Dark streak on paper	$AgSbS_2$
Pyrargyrite	light gray-blue (against galena)		Strong	abundant carmine red	Visible	-	-	Streak on paper	Ag_3SbS_3
Proustite	light gray-blue (against galena)		Strong	Blood-red to brick-red	Visible	-	-	-	Ag_3AsS_3
Stephanite	faint rose (against galena)		Strong	-	Weak	-	-	-	Ag_5SbS_4
Stromeyerite	faint violet-rose (against galena)		Strong	-	In oil, strong	Noticeable	-	-	AgCuS
Tetrahedrite	gray to brown, olive or greenish (against galena) **olive-white**		Isotropic	variable strong in Te, low in Sb tetrahedrite	-	-	No cleavage, brittle	-	$(Cu,Fe,Zn,Ag)_{12}(Sb,As)_4S_{13}$

(underlined found in ores studied)

Detailed mineralogy of the 34 samples

To compare the mineralization of the several sets of veins comprising the deposits requires detailed examination of the individual representative samples; following is a description of the mineralogy, relationships, etc. of the various samples.

W50 - 1 "Promontorio mine, level 50 Chiflon 133 S. Part of main vein of Veta Madre. Gold and silver ore, showing prominent bands of sulfides." I.F.W.

Polished sections 599, 500, (Howard) 001.

The specimen is a rather coarse white marble, with numerous thin bands, a millimeter or so wide, of dark ore grains. The bands are discontinuous, showing small off-sets. With a hand lens sphalerite and chalcopyrite are seen; in polished section there are also seen galena, "argentite", and gold-silver (electrum). These, with pyrite and sometimes marcasite, are the ore minerals that have been found consistently in the Guanajuato ores studied in this investigation. (Polybasite, pyrargyrite and argyrodite, have also been found as relatively large crystals with the ore, but these minerals have been recognized only rarely in the polished ore sections. Apparently in the twenty-three years since Wandke and Martinez' account of the Guanajuato ores was written, the character of the ore has changed; these authors say, "the ores consist of silver sulfides and silver sulphantimonides with which occur, in minor and almost insignificant amounts, such base minerals as galena, sphalerite, and chalcopyrite." On the contrary, the mineralized vein material now mined consists largely of these base minerals, especially sphalerite and chalcopyrite, with pyrite. The values appear to be almost solely in "argentite" (acanthite) and native gold-silver (electrum).

The galena present in these ores is seldom visible to the naked eye, and even under the microscope the grains are usually so small that the diagnostic cubic cleavage is often not seen. However, the color, reflectivity, isotropy, and diagnostic cleavage (when present) identify the mineral beyond question. Sphalerite gives the ore-veinlets their dark gray color; under the microscope it is recognized by low reflectivity, isotropy, internal reflection, and almost unfailing inclusions of chalcopyrite. Chalcopyrite is easily differentiated from gold (electrum) and pyrite by its different yellow color, inferior hardness compared to pyrite, and anistropy with lamellar twinning. Pyrite is often euhedral, and sometimes shows corrosion (?) described in detail below. Sometimes there is an indefinite zoning or intergrowth of two slightly different types of pyrite; of contrasting color and relief (i.e. hardness). Where the pyrite forms large masses, it is further sometimes spongy in texture suggesting crystallization from a gel. Marcasite is associated with pyrite occasionally, but the relations are not clear. "Argentite" is recognized by its softness, greenish hue against galena, and anisotropy (all of the so-called "argentite" is really acanthite, the stable low-temperature dimorph). Owing to its softness, argentite may have been gouged out to an unknown extent in preparation of the polished sections studies, and some, at least, of the numerous holes in the sections may represent original argentite, which would be therefore even more abundant than these polished sections would indicate.

Gold-silver is much brighter than either chalcopyrite or pyrite, and distinctly yellower. It usually is badly scratched, owing to its softness. It occurs characteristically as minute rounded grains, with the sulfide minerals.

The ore grains (except pyrite) are completely anhedral and well-defined sequence of crystallization can seldom be recognized. The inclusion of one of the ore minerals by another is generally reciprocal, and in any event, this is an ambiguous criterion. In other specimens, however, clear replacement of galena by argentite is shown (W50 - 11, polished section 591).

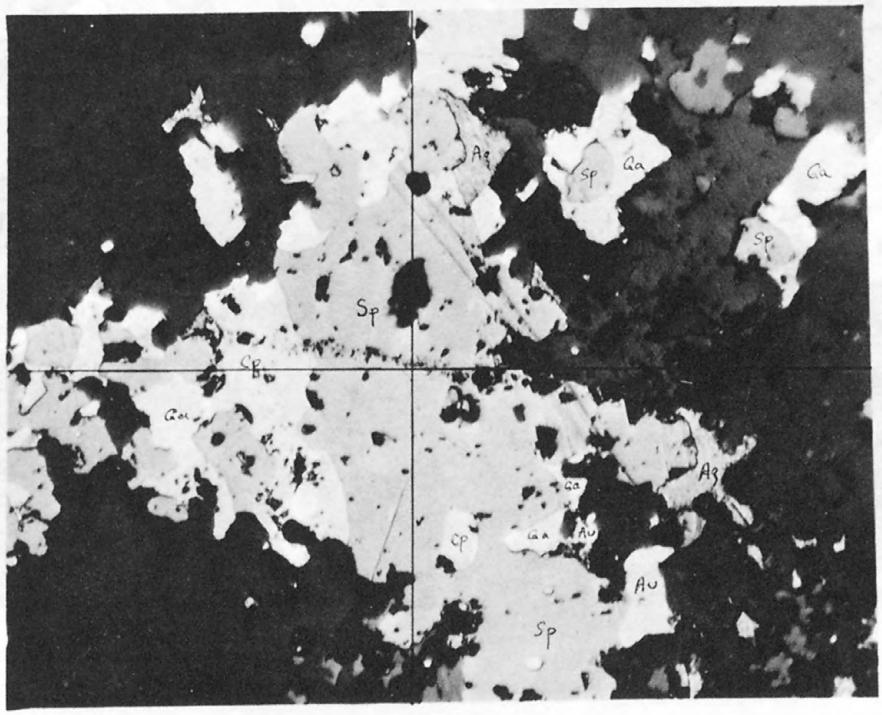
Wandke and Martinez/ list the following metallic minerals from the Guanajuato District:

Arsenopyrite
*Chalcopyrite
**Tetrahedrite
Cinnabar
Galena
Guanajuatite
Marcasite
Molybdenite
*Pyrite
**Sphalerite
Stibnite
Native Gold
Raumonite (?? C.M.)
Native Silver
*Argentite
Miargyrite
Pyrargyrite
*Polybasite
Aguilarite
Naumannite
Embolite
Cerargyrite
Psilomelane

* Common to the veins and abundant.
** Common to the veins but best seen under the microscope.

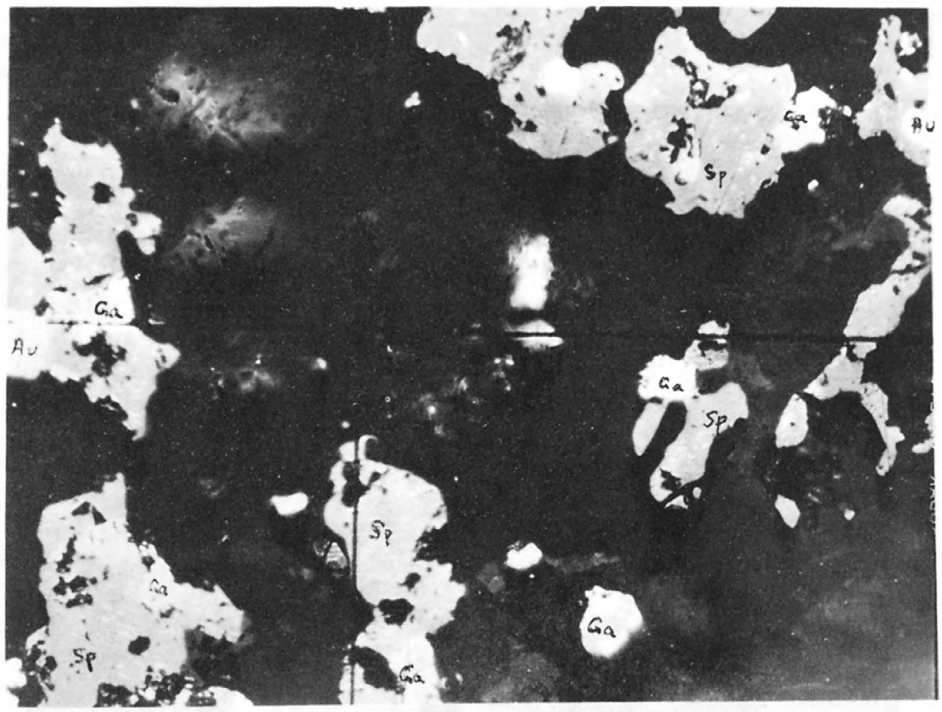
It is rather remarkable that tetrahedrite, listed by Wandke and Martinez as "common to the veins but best seen under the microscope" was not observed at all in this study (except perhaps in W50 -43A). Only the underlined minerals were found. Pyrargyrite was identified as a crystalline mass (W50 - 19B) from the Rayas Mine, but not noted in the polished surfaces. Polybasite, similarly, was noted in crystalline masses on the ore specimens (W50 - 3, Rayas Mine and W50 - 39 also Rayas Mine), but very rarely recognized in the polished surfaces.

Argyrodite and covellite are not listed by Wandke and Martinez, but have been identified in these specimens.



W50 - 1 X160 Harvard 001)

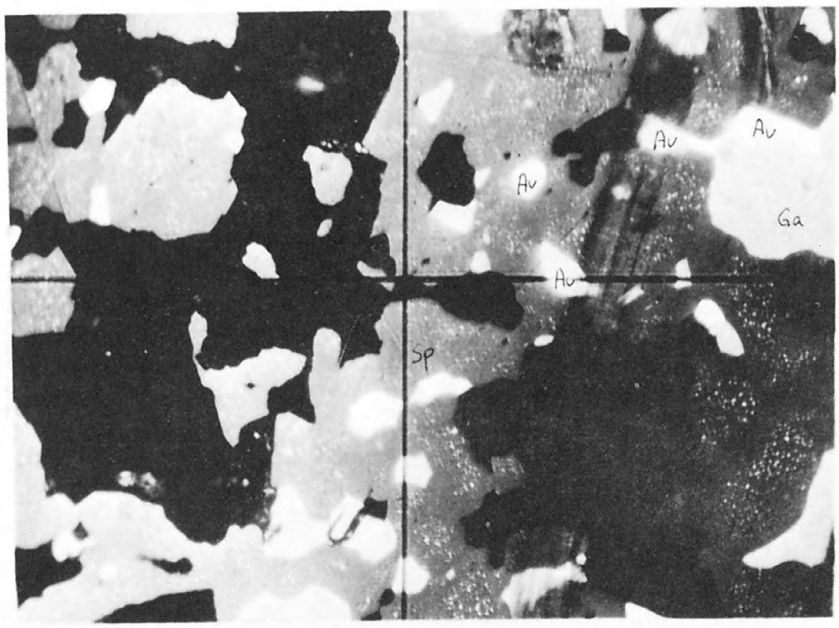
Chalcopyrite, galena, sphalerite with argentite and gold.
Cp Ga Sp Ag Au
Shows typical mutual relations of the three (with pyrite) most abundant ore minerals.



W50 - 1 X350 (Harvard section 001)

Galena (Ga), Sphalerite (Sp) with minute chalcopyrite inclusions and Gold (Au).

The disseminated ore grains are characteristic. Chalcopyrite and argentite are also associated (not in this picture). Pyrite is usually more segregated.



W50 - 1 X350 (Harvard section 001)

Sphalerite (Sp) with inclusions of chalcopyrite, Galena (Ga) and Gold (Au).

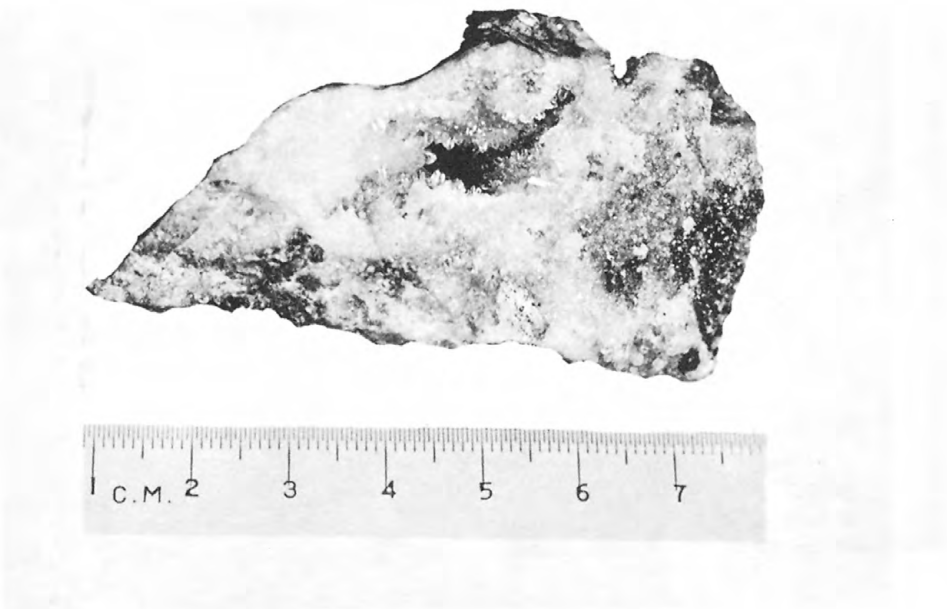
W50 - 3 "Rayas mine level 275 S., Pozo 87 N., cross vein in HW of Santa Margarita, N 25 W. Gold and silver ore showing vuggy quartz with good sulfide crystals, also sulfides scattered through wall rock." I.F.W.

Polished sections 590 and 597.

These two polished sections show only disseminated pyrite, with traces of chalcopyrite. The hand specimen is breccia cemented by vuggy quartz, in which the usual sphalerite-rich ore minerals are locally segregated. The brecciated wall fragments however appear to contain only disseminated pyrite.

Part of the hand specimen is coarse marble.

Black crystals in quartz vug identified as polybasite (X-ray film 5279) (along with chalcopyrite, galena, sphalerite, etc.

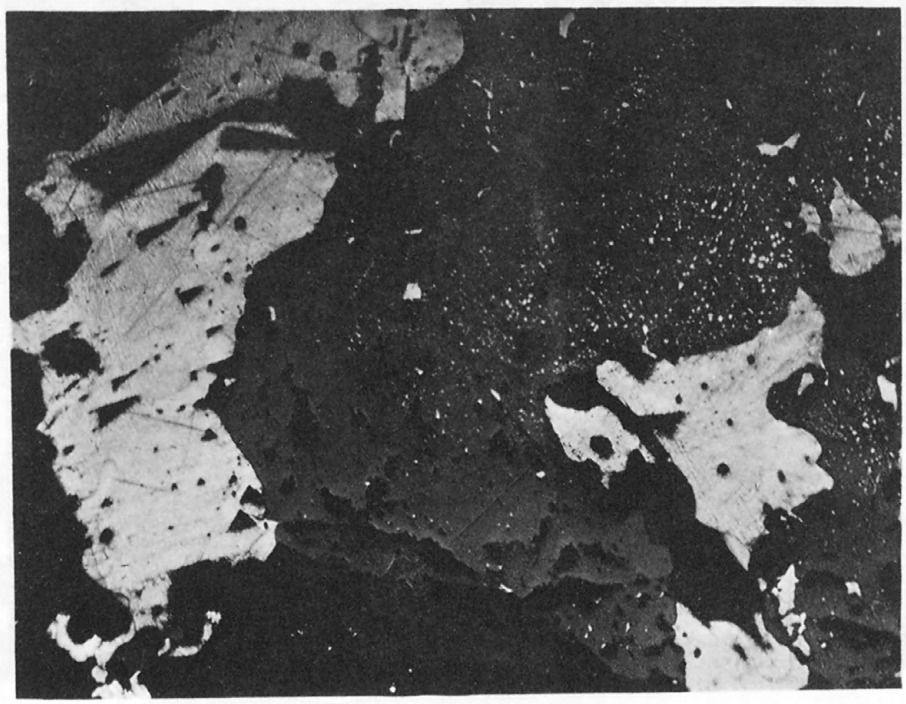


W50 - 3 Shows vuggy quartz cementing breccia. At the right is a dark area rich in sulfides. This type of rock is characteristic of the Guanajuato ore. Polybasite and argyrodite crystals are present in the vugs.

W50 - 5 "Rayas mine, 275 level, drift 275S. Santa Margarite vein (N 32° W). Gold and silver ore, with prominent patches of sulfides." I. F.W.

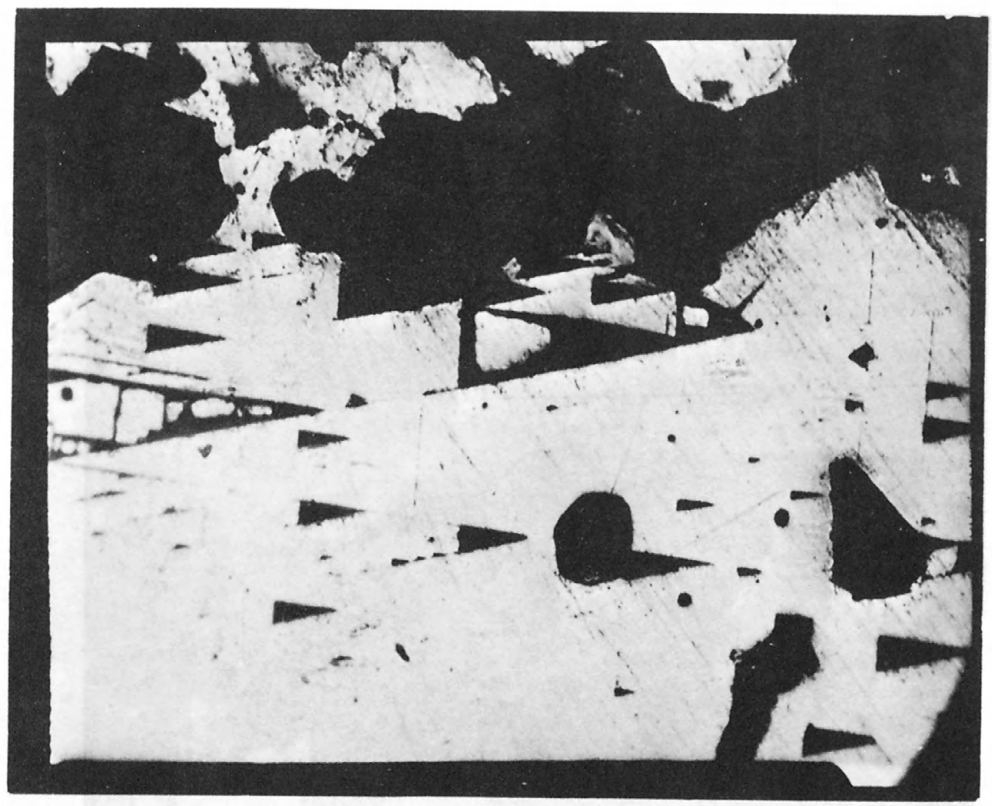
Polished sections 585, 655, 656.

Specimen is coarse drusy somewhat amethystine comb quartz, with much coarsely crystallized calcite. A gray band 1/2 inch across contains much disseminated euhedral pyrite; in the quartz are segregations 1/4 inch across which contain sphalerite, chalcopyrite, galena, and minor pyrite. A very little argentite was noted. Pyrite occurs as euhedral inclusions in the other minerals, which may therefore be younger than the pyrite.



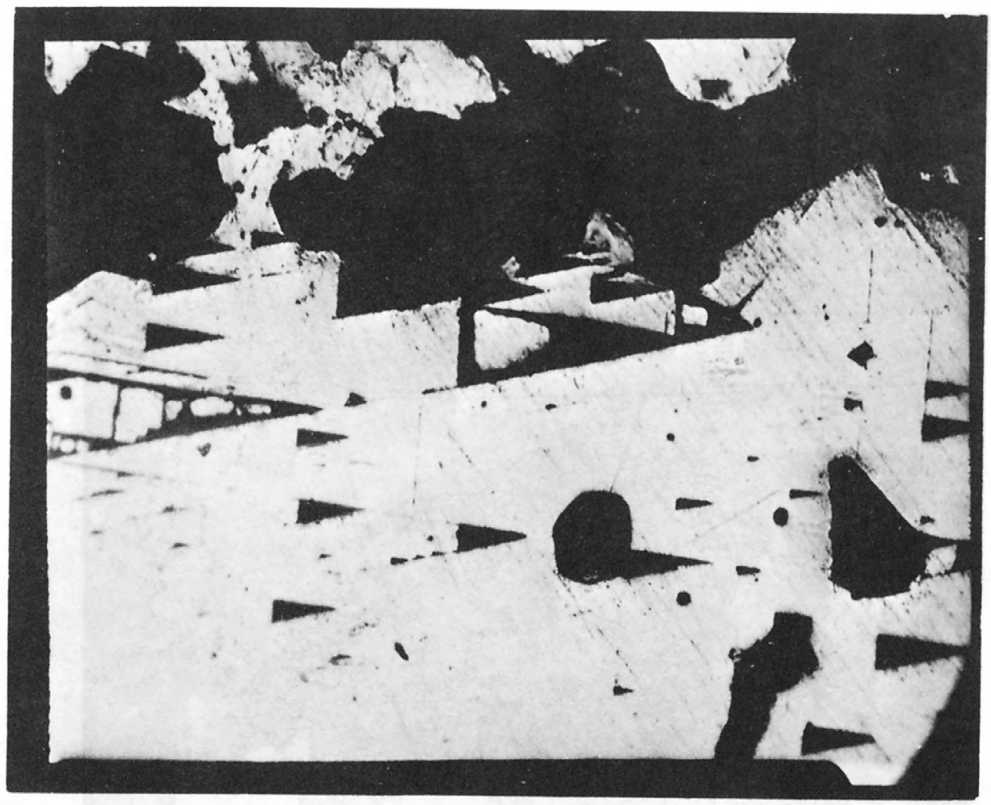
W50 - 5 X150 Polished section 655

Galena (Ga), Sphalerite (Sp), Chalcopyrite (Cp)



W50 - 5 X150 (Polished section 655)

Coarse galena, showing cubic cleavage. The galena is usually too fine-grained to show good cleavage. Euhedral quartz is shown (upper left).



W50 - 5 X150 (Polished section 655)

Coarse galena, showing cubic cleavage. The galena is usually too fine-grained to show good cleavage. Euhedral quartz is shown (upper left).

W50 - 6 "Rayas mine, Winze 12S, about 18 m. below 275 level San Martin vein (N 73° W). Pozo 12 S. Gold and silver ore, with patches of chalcopyrite, and other sulfides; also dark streaks high in silver." I.F.W.

Polished sections 601 and 611.

Siliceous breccia, is part marble, with heavily pyritized grey-green wall rock, and dark ore streaks in the quartz.

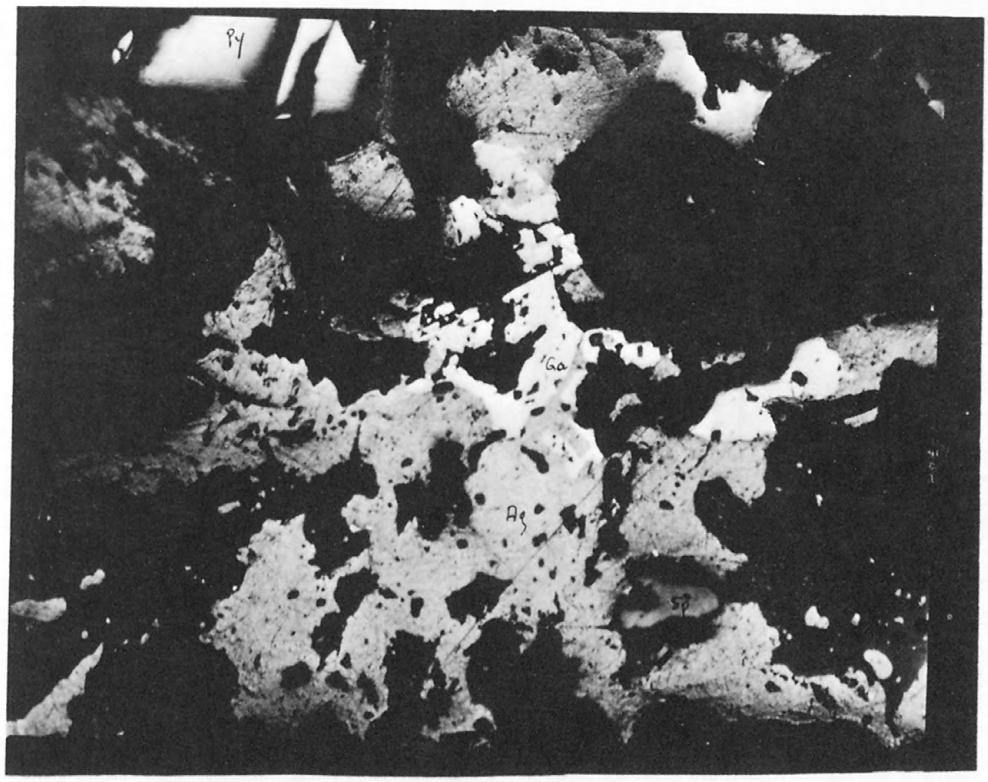
Polished section 601 shows pyrite, chalcopyrite, galena, sphalerite, and scanty argentite. Polished section 611, representing the pyritic wall rock, shows predominant pyrite, with very little sphalerite.

W50 - 8 "Rayas mine, winze 35 N. Frente Sur, about 5 m. below 275 level. Cuatro, or Medio vein (N 65° W). Goldand silver ore, with dark streaks of sulfides rich in silver." I.F.W.

Vein quartz with vugs, partly amethystine, cutting pyritized grey green country rock.

Polished section 596.

In this section, the major mineralization is located in the pyritized wall rock. Argentite is abundant.



W50 - 8 X150 (Polished section 596)

Pyrite, Galena, Argentite, Sphalerite.

Chalcopyrite was not found in this section, although relatively large grains are present in the hand specimen.

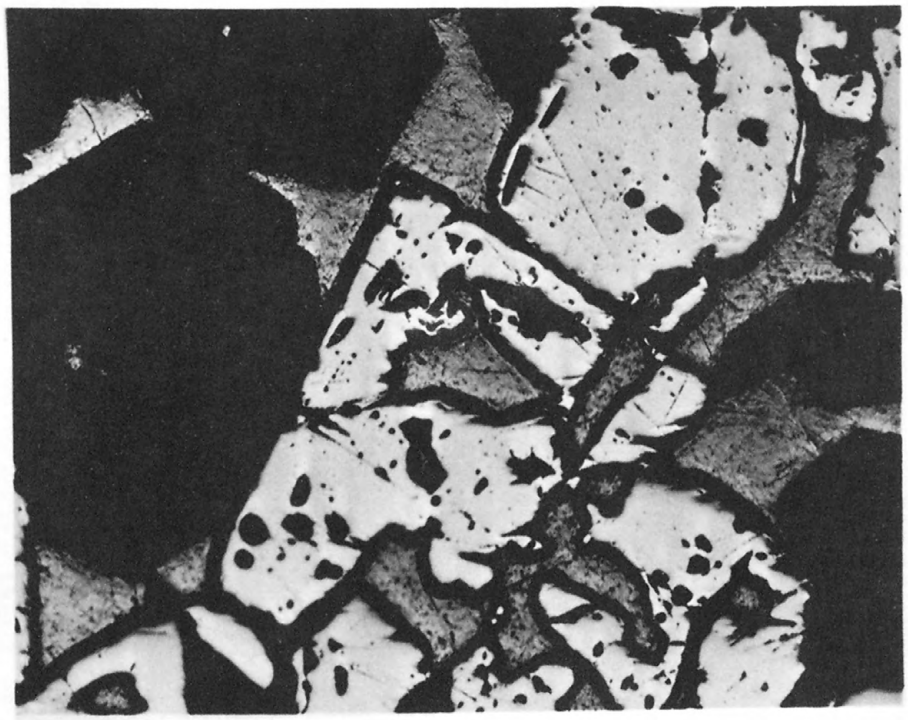
W50 - 11 "Rayas mine, 255 level S., Crucero alto 18 S., unnamed vein striking N 85° E. Gold and silver ore; assays high in gold; many patches of sulfides." I.F.W.

Polished sections 591, 593, 699.

Quartzitic rock with abundant sulfides, including coarsely crystallized argentite (X-ray film 5758).

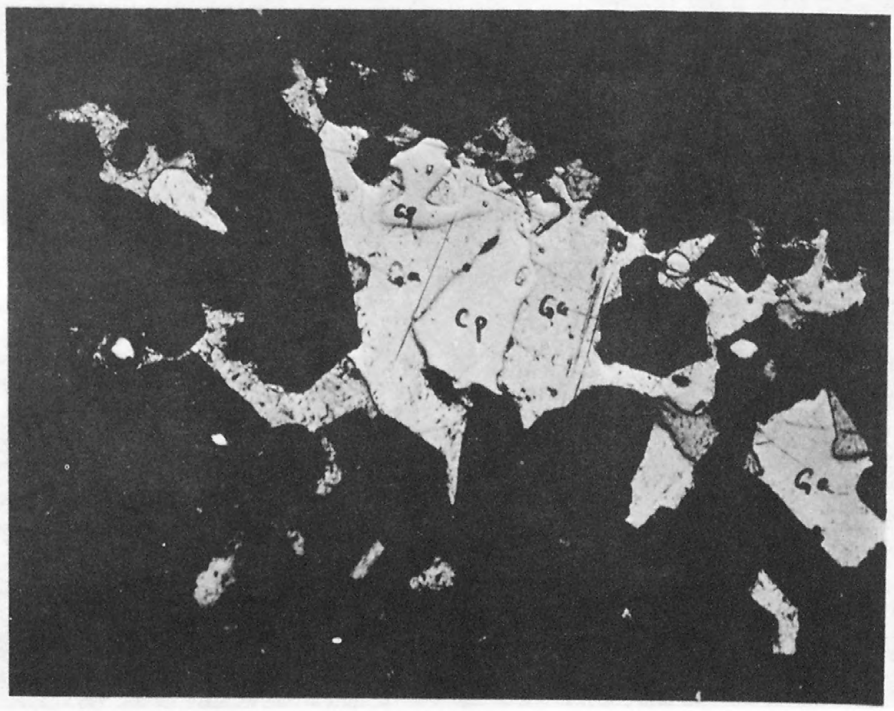
The polished sections show abundant argentite with free gold.

W50 - 11 Argentite on quartz X50



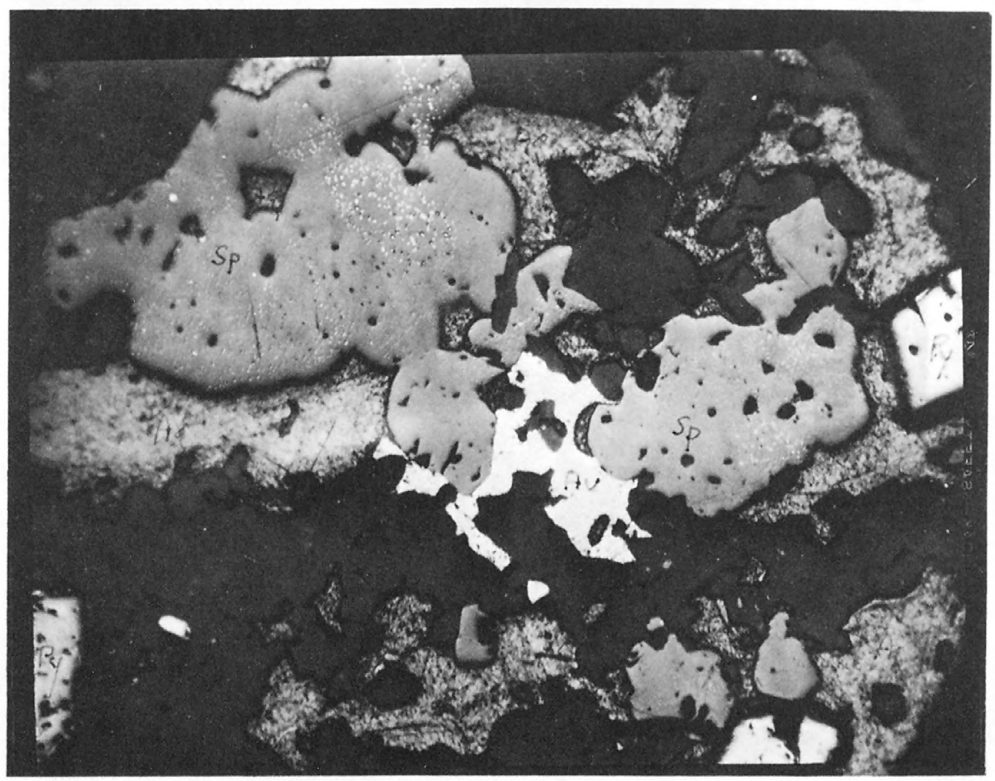
W50 - 11 X150 (Polished section 591)

Pyrite, argentite, and quartz.



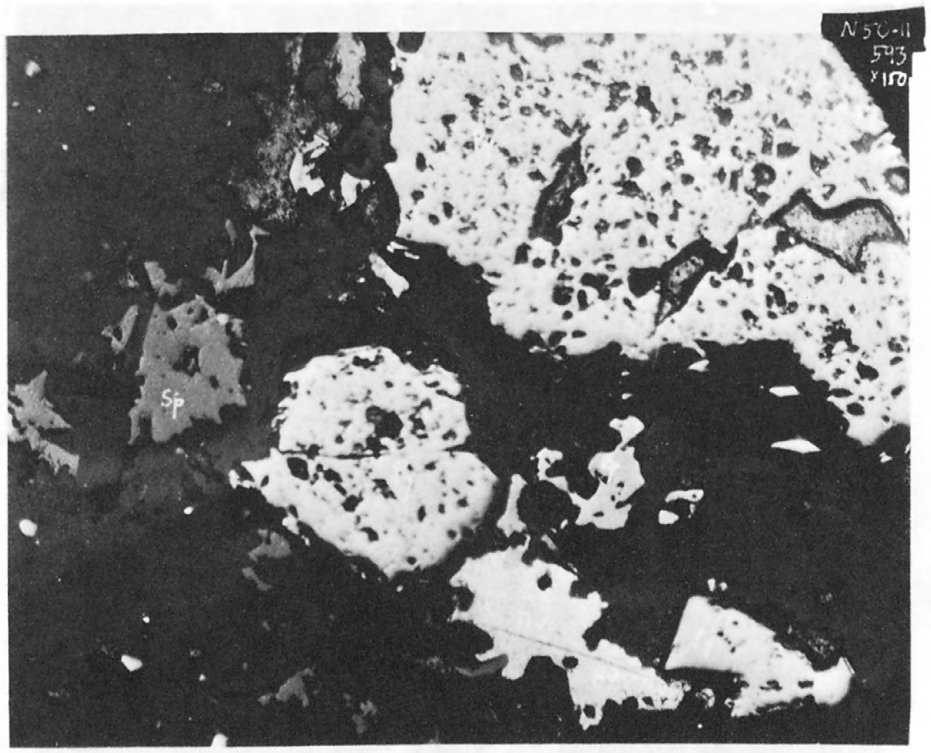
W50 - 11 X150 (Polished section 591)

Galena, chalcopyrite, argentite (dark grey).



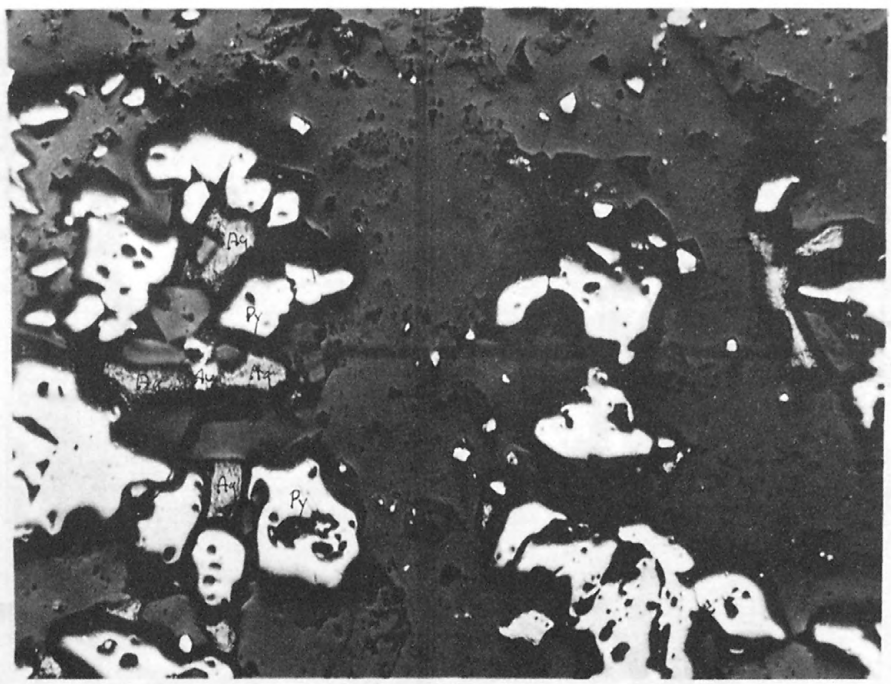
W50 - 11 X150 (Polished section 593)

Gold (Au), Argentite (Ag), Pyrite (Py), Sphalerite (Sp) with minute chalcopyrite inclusions.



W50 - 11 X150 (Polished section 593)

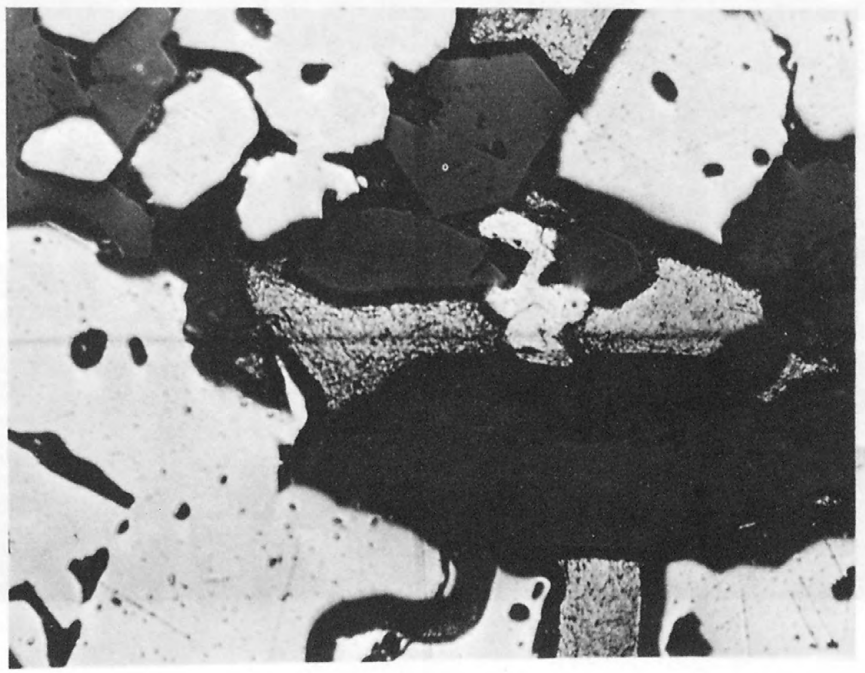
Pyrite, gold, chalcopyrite, sphalerite, argentite.



W50 - 11 X125 (Polished section 591)

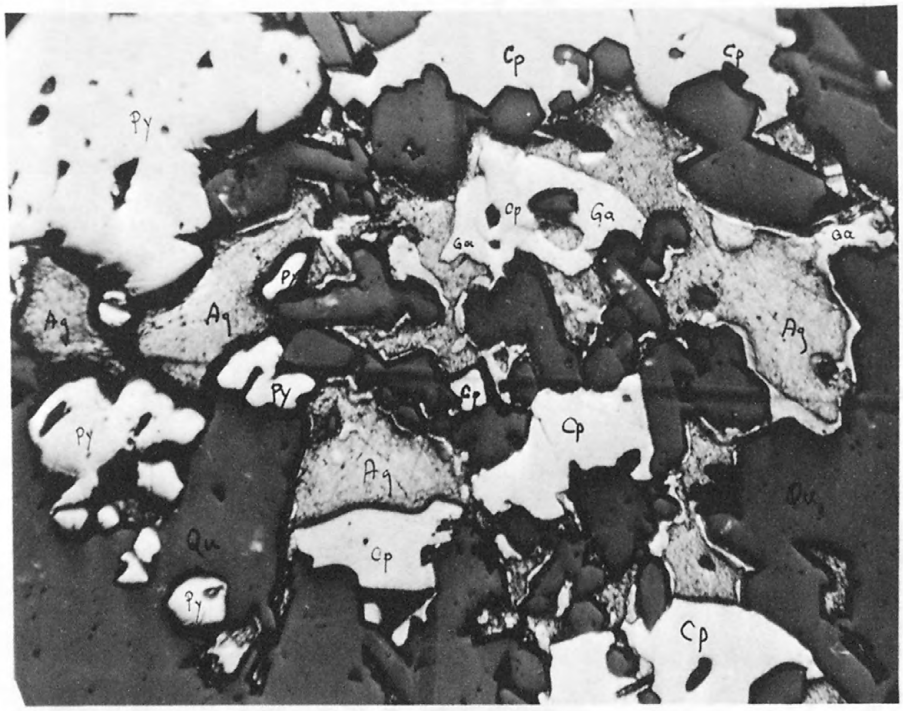
Gold (Au), Argentite (Ag), Pyrite (Py), and Chalcopyrite (Cp).

Shows characteristic association of gold and silver-sulfide.



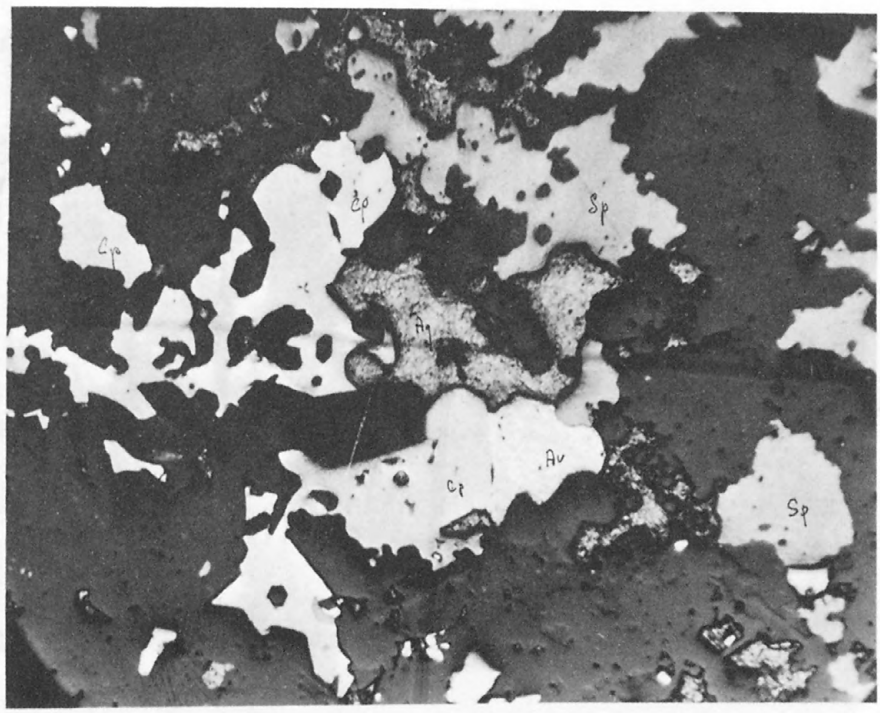
W50 - 11 X375 (Polished section 591)

Enlarged view of previous figure showing pyrite - gold - argentite in quartzitic matrix.



W50 - 11 X150 (Polished section 591)

Shows replacement of galena by argentite. Note unreplaced rims of galena enclosing argentite.



W50 - 11 X150 (Polished section 591)

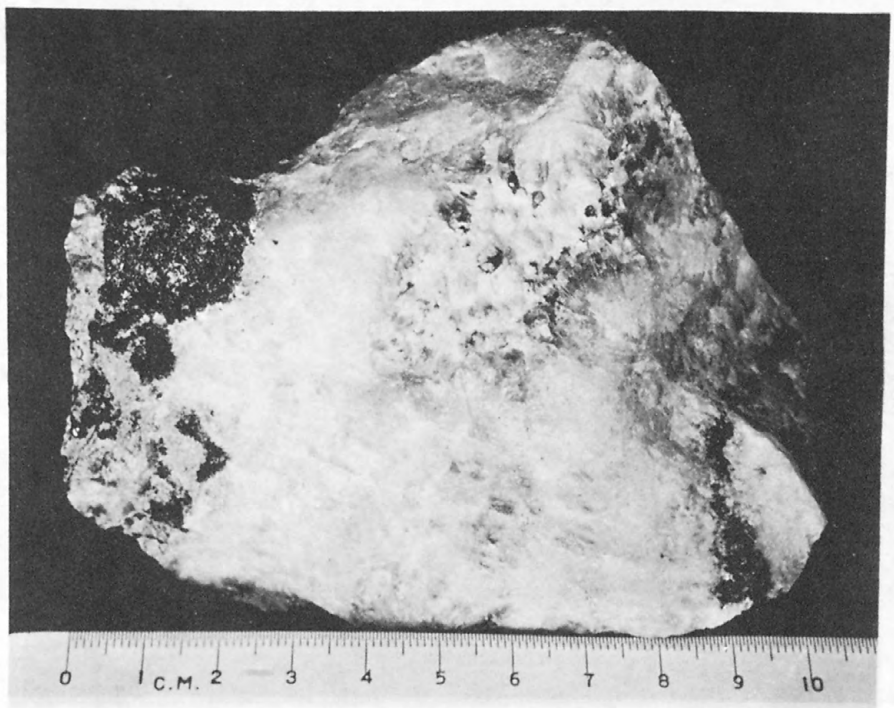
Gold and argentite, with chalcopyrite and sphalerite. Note molding of chalcopyrite against quartz crystals.

W50 - 13 "Rayas mine, level 260 Chiflon 20 S. San Martin vein N 75° W." (E.W.
(On the specimen label, "unnamed vein").

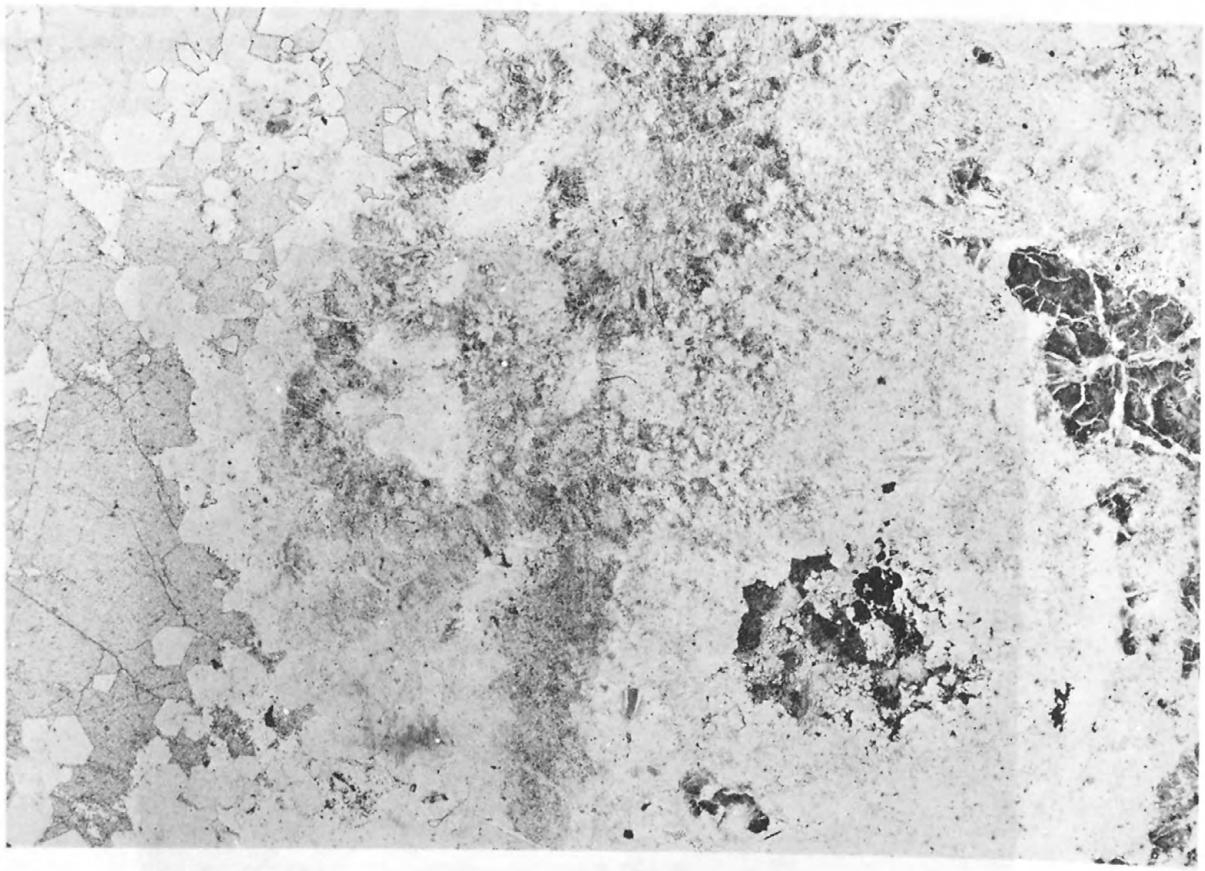
Polished section 587 (thin section).

Two different specimens are labeled W50 - 13 - (a) brownish-gray siliceous rock with quartz veins, and (b) amethystine quartz with dark siliceous areas containing sulfides. In one place the amethyst crystals are coated with a druse of dolomite-ankerite (w = 1.69).

Same type of ore - argentite, gold, chalcopyrite, galena, sphalerite, and pyrite.

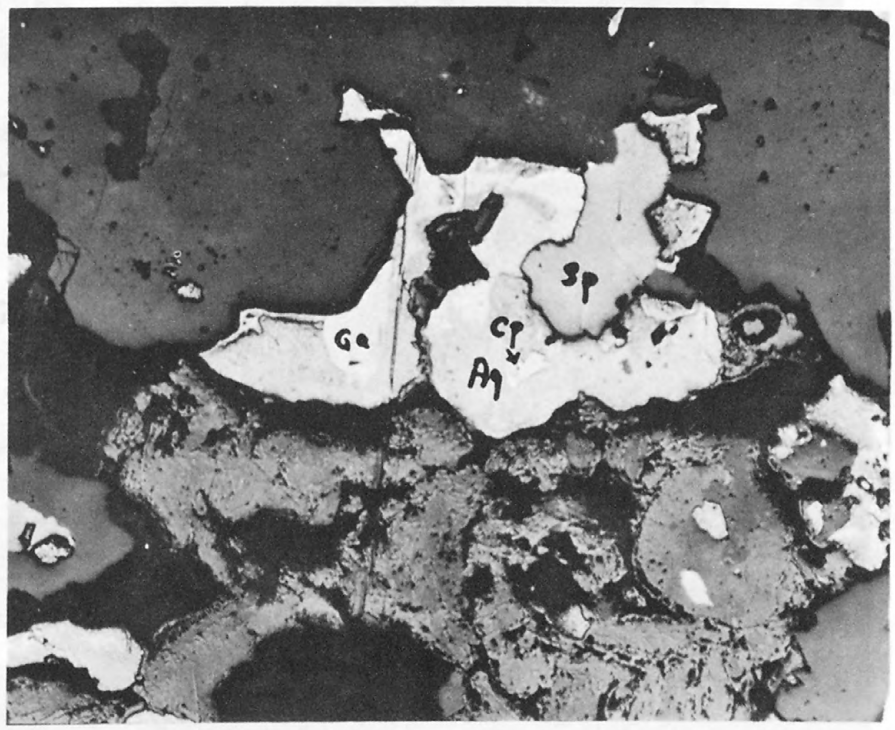


W50 - 13 Amethystine quartz, with dark areas carrying sulfides (left and right ends). The dull white area (upper center) is a druse of whitish dolomite-ankerite.



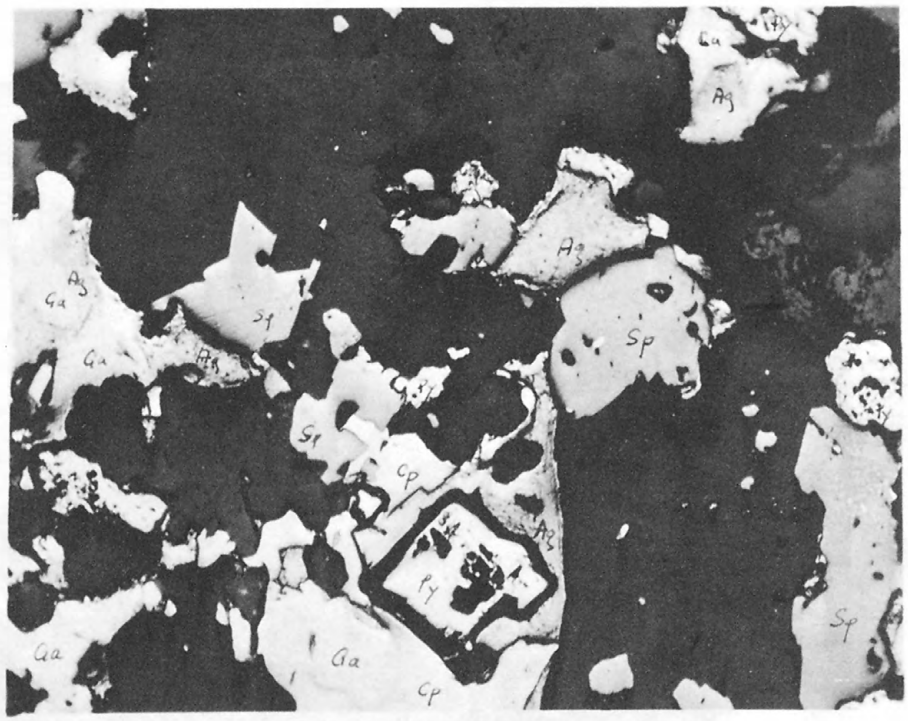
W50 - 13 X12 Thin section

Brownish gray rock, with quartz veins. The left side of the picture shows much rhombohedral carbonate; at the right the dark area are saponite optically similar to that of W50-47.



W50 - 13 X150 (Polished section 587)

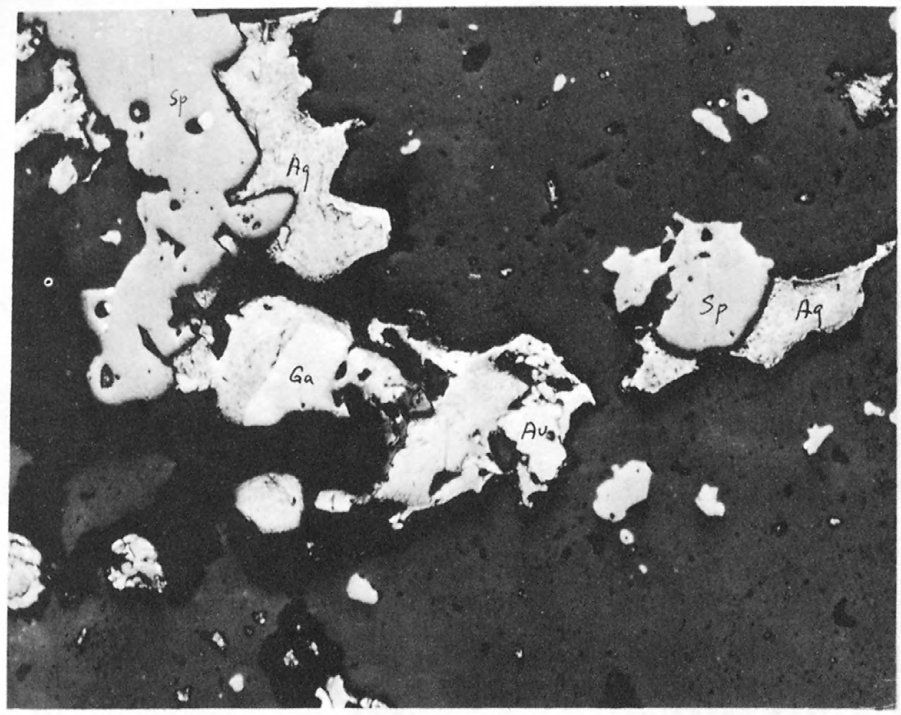
Argentite, galena, sphalerite, and chalcopyrite. The argentite is replacing galena, which is molded on quartz crystals.



W50 - 13 X150 (Polished section 587)

Chalcopyrite (Cp), Galena (Ga), Pyrite (Py), Argentite (Ag), Sphalerite (Sp).

Shows characteristic aspect of Guanajuato ore. Only pyrite is often euhedral. Note sphalerite (left of center) molded on vuggy quartz.



W50 - 13 X150 (Polished section 587)

Gold (Au), Sphalerite (Sp), Argentite (Ag), Galena (Ga).

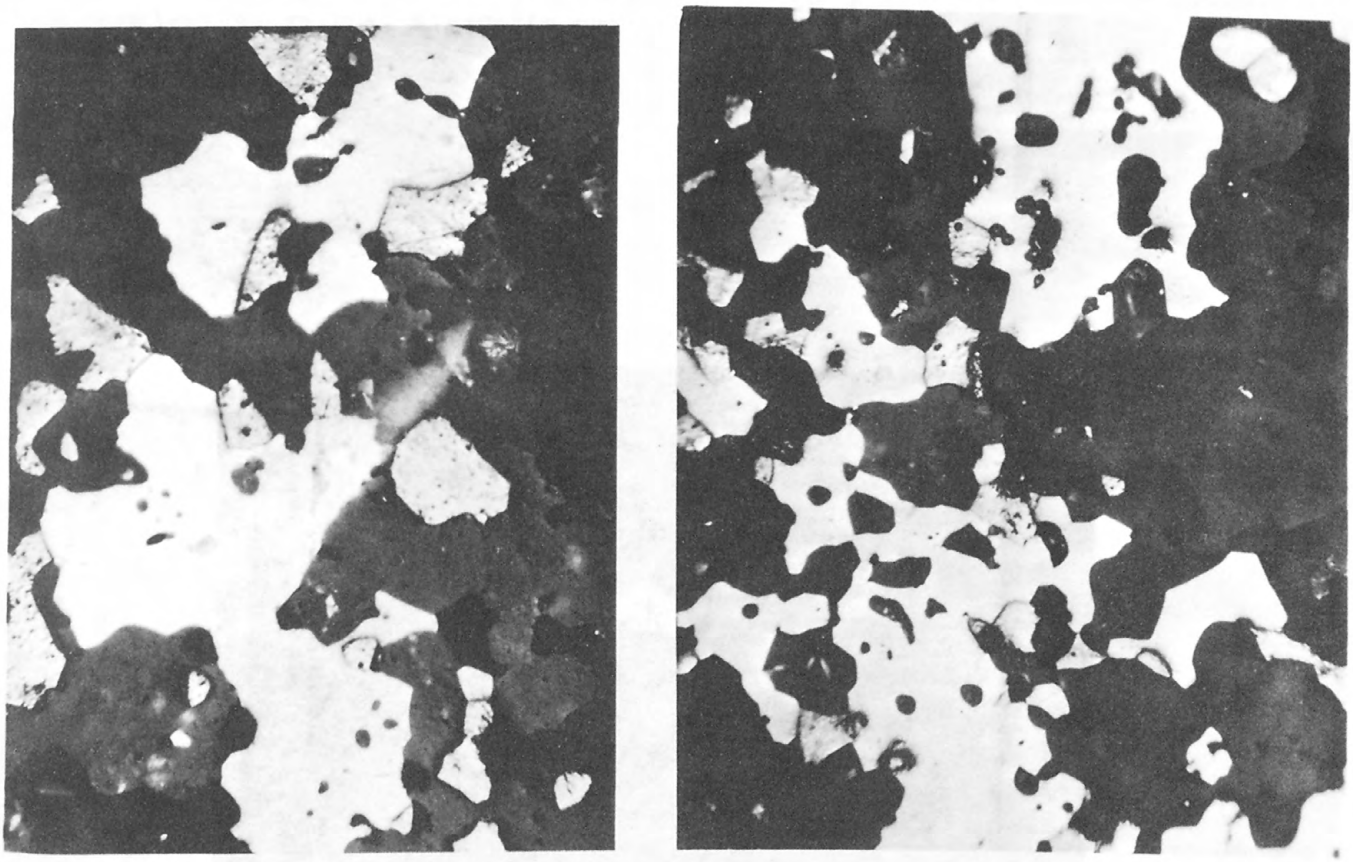
W50 - 15 "Rayas mine, 230 level S. Footwall portion of main veing of Veta Madre, N 55° W. Gold and silver ore showing dark sulfide streaks high in silver." I-F.W.

Polished sections 595, 610.

Section 595 - Pyrite, chalcopyrite, sphalerite, galena.

Section 610 - Similar, much less pyrite. The specimen is a white marble with quartz vugs, and some amethystine quartz, with disseminated ore.

The dark streaks are interrupted veinlets or bands of fine-grained sphalerite, chalcopyrite, galena, and more or less pyrite. The galena shows little or no characteristic cleavage. It may carry part of the silver in the ore, although Ramdohr notes that galena can carry only C.1% of Ag_2S in "solid solution" - more silver if present is in perhaps unrecognized silver minerals.

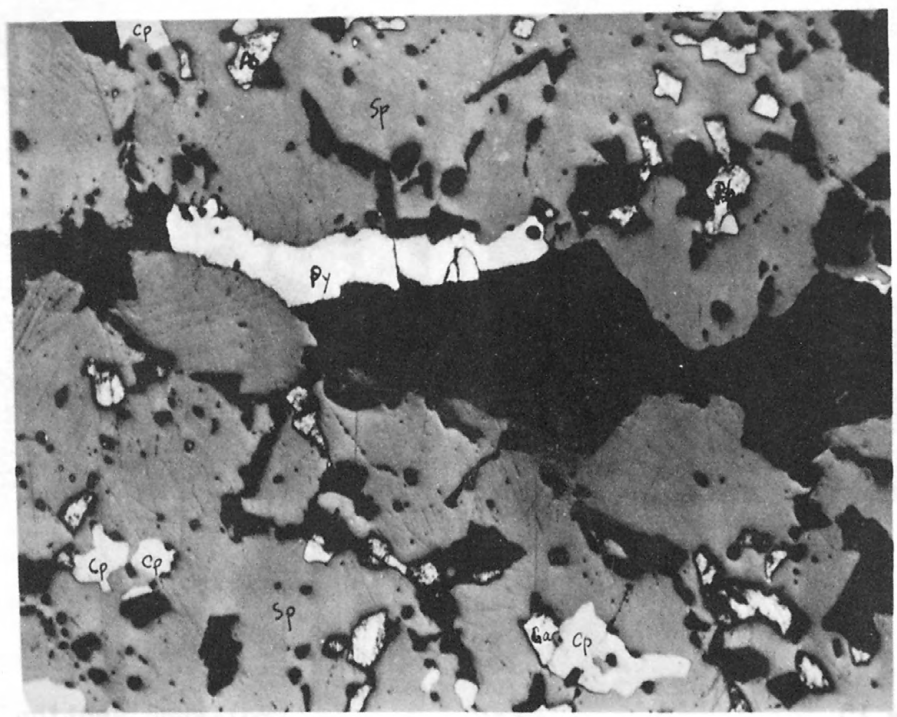


W50 - 15 X350 (Polished section 610)

Rayas mine, 230 level south. Footwall portion of main vein of Veta Madre N 55° W.

Galena, Sphalerite, and Chalcopyrite.

Shows range in coarseness of ore grains, and characteristic texture and relations of ore minerals.



W50 - 15 X150 (Polished section 610)

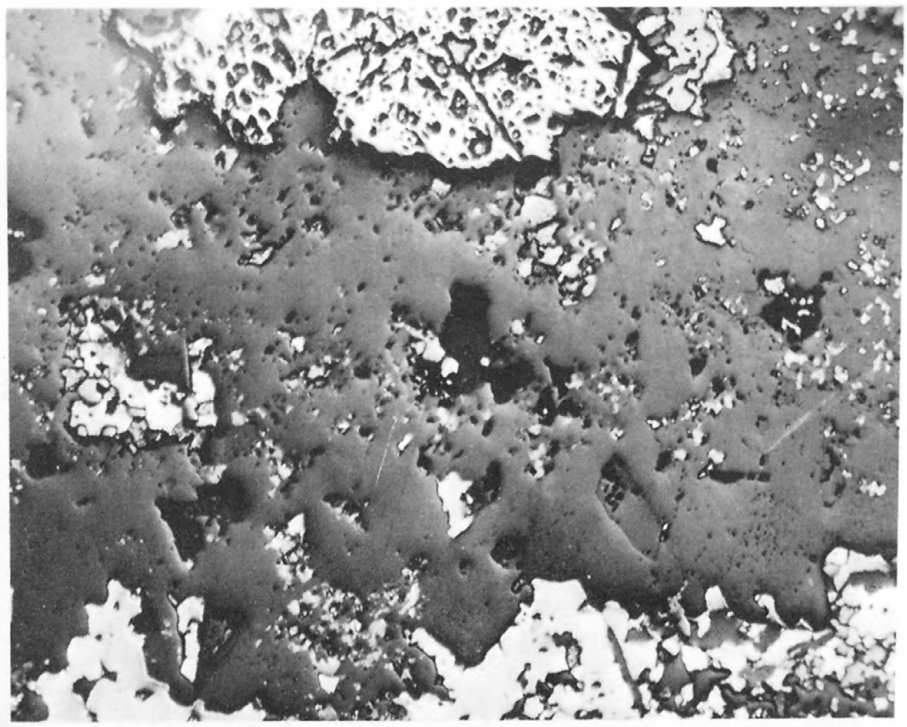
Chalcopyrite (Cp), Galena (Ga), Sphalerite (Sp), and Pyrite (?) (Py).

W50 - 18 "Rayas mine, level 230 S. Rebaje 300 S. Frente Tercera Norte, Santa Cecilia vein N 85° W." I.F.W.

Polished section 594

Silicified marble - breccia, with conspicuous sulfide streaks, dark from much sphalerite. Quartz amethystine in part.

In polished section shows the usual pyrite, chalcopyrite, gold, sphalerite, galena, argentite aggregate.

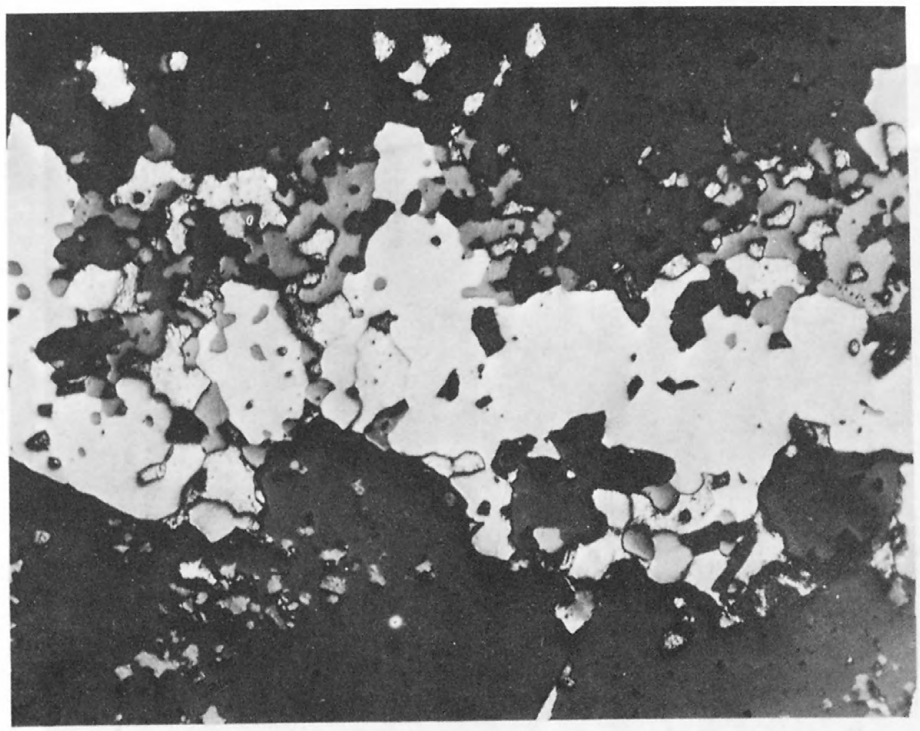


W50 - 18 X65 (Polished section 594)

Pyrite (upper edge)

Galena - argentite - sphalerite (left center)

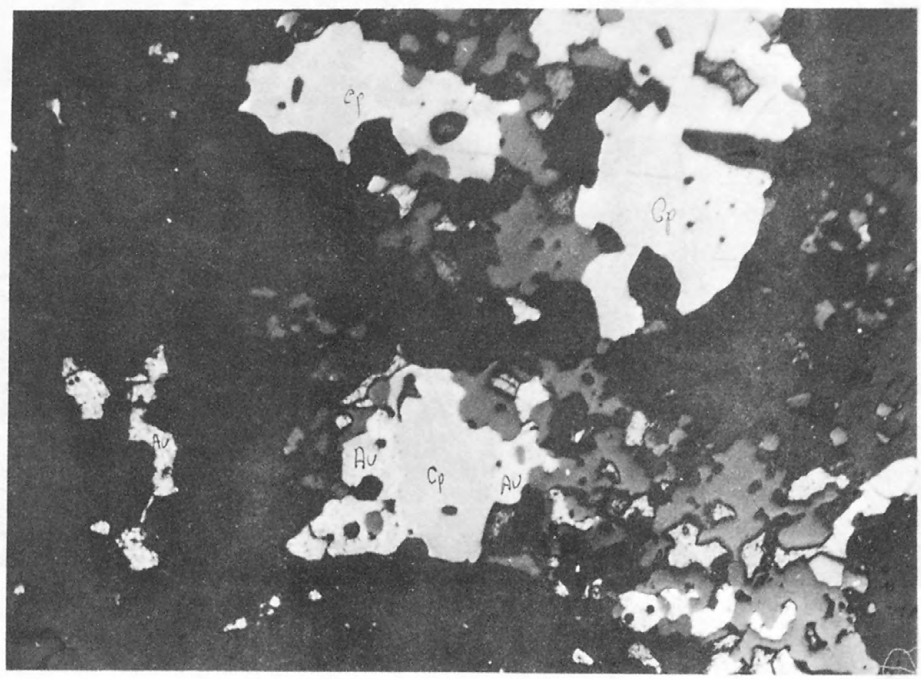
Main ore "veinlet" - bottom - with much chalcopyrite



W50 - 18 X150 (Polished section 594)

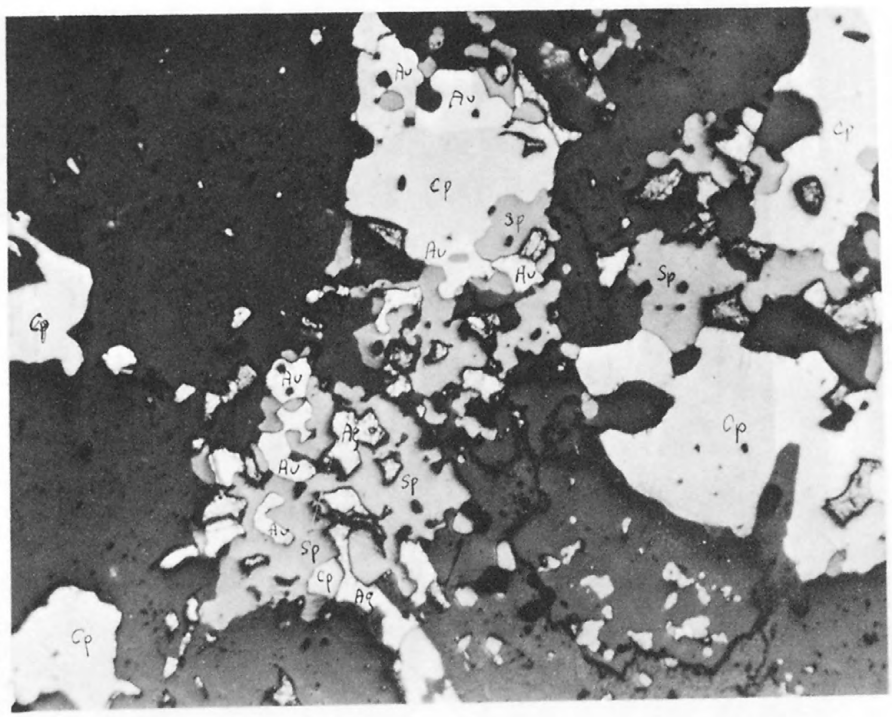
Chalcopyrite, gold, sphalerite, galena, pyrite, argentite.

The gold particles are n in the upper part of the picture, with arrows pointing to



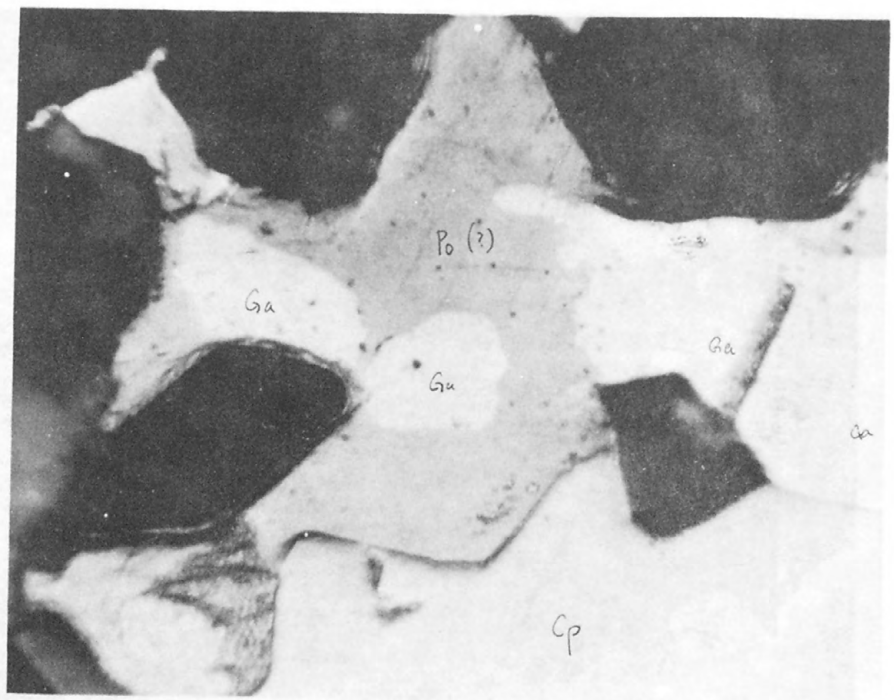
W50 - 18 X150 (Polished section 594)

Rich gold ore. Chalcopyrite (Cp) bordered with gold. Also sphalerite (Sp) enclosing galena (lower right).



M50 - 18 X150 (Polished section 594)

Rich gold-silver ore.
Gold, argentite, chalcopyrite, sphalerite.



W50 - 18 X375 (Polished section 594)

Unknown mineral, probably polybasite, associated with galena and argentite (also gold, chalcopyrite, sphalerite) in rich gold-silver ore.

W50 - 19 "Rayas mine, level 260 S. Chiflon 20 S, San Martin vein N 80° W. Gold and silver ore, with patches and bands of sulfides between quartz and wall rock." 1-F.W.

Polished section 616

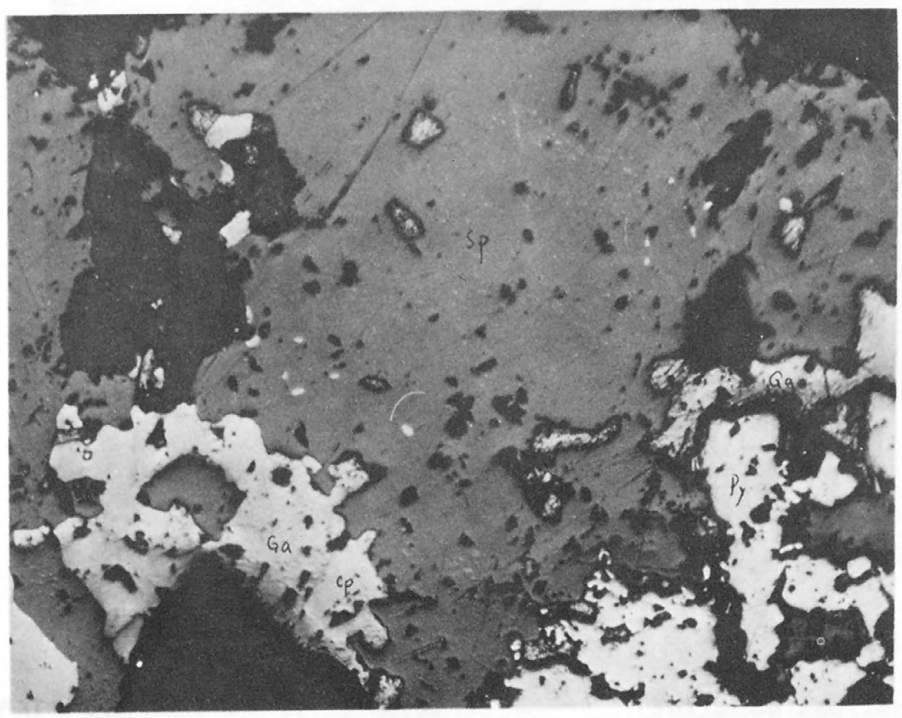
Quartz vein, 1 - 2 cm. wide, amethystine towards middle, cutting gray green wall rock, bordered with irregular veinlets and pea-shaped masses of sulfides. Wall rock is pyritic. Coarse pinkish carbonate is present in the quartz.

Although no silver minerals were noted in the polished section, coarsely crystallized argentite and pyrargyrite from the same locality were verified as such, by x-ray (films 5762 and 5280, respectively).

W50 - 19A Crystals of argentite (X-ray 5762)

W50 - 19B Pyrargyrite (X-ray 5280)

Rich dissemination of pea-sized masses in quartz.



W50 - 19 X150 (Polished section 616)

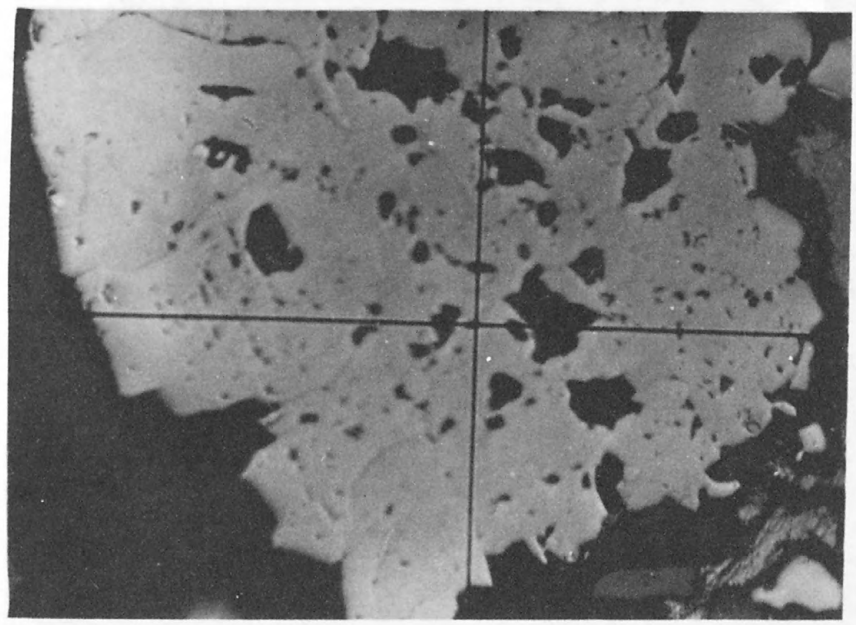
Chalcopyrite, galena, pyrite, with much sphalerite.

W50 - 20 "Rayas mine, 230 level S. Footwall portion of main vein of Veta Madre N 55° W. Gold and silver ore, with prominent bands of sulfide." I. F.W.

Polished section 615.

This is a grey siliceous (quartzitic) rock, with white quartz veins containing calcite. The grey rock is pyritic; the ore minerals appear to be concentrated along the outer part of an inch wide quartz vein.

The polished section shows very well the complex intergrowth of the base-metal minerals, making mechanical separations very difficult if not impossible.

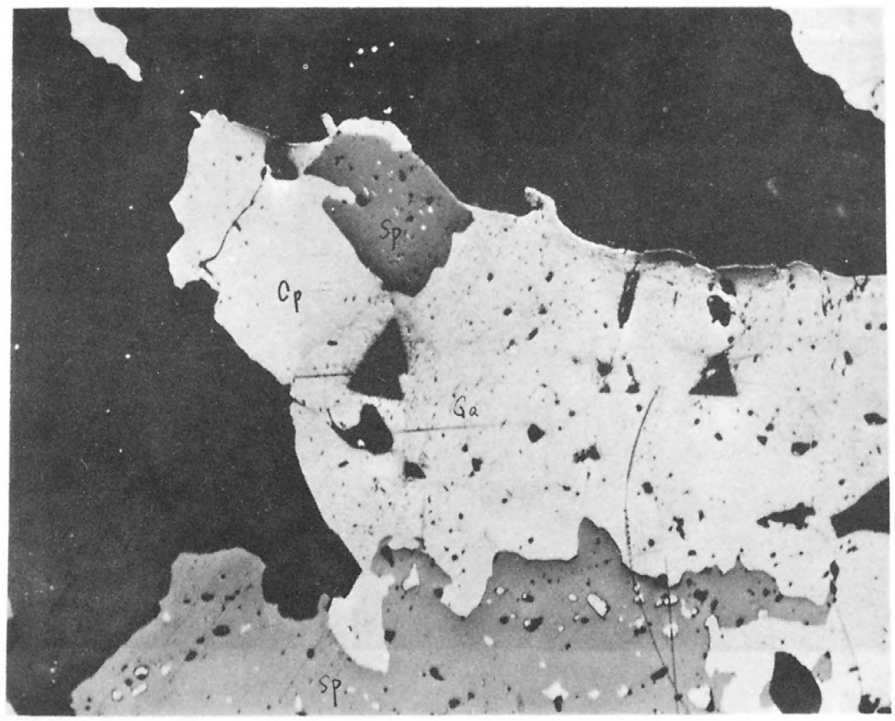


W50 - 20 X350 (Polished section 615)

Rayas mine, 230 level S. Footwall portion of main vein of Veta Madre N 55° W.

~~Pyrite, galena, chalcopyrite, and sphalerite.~~

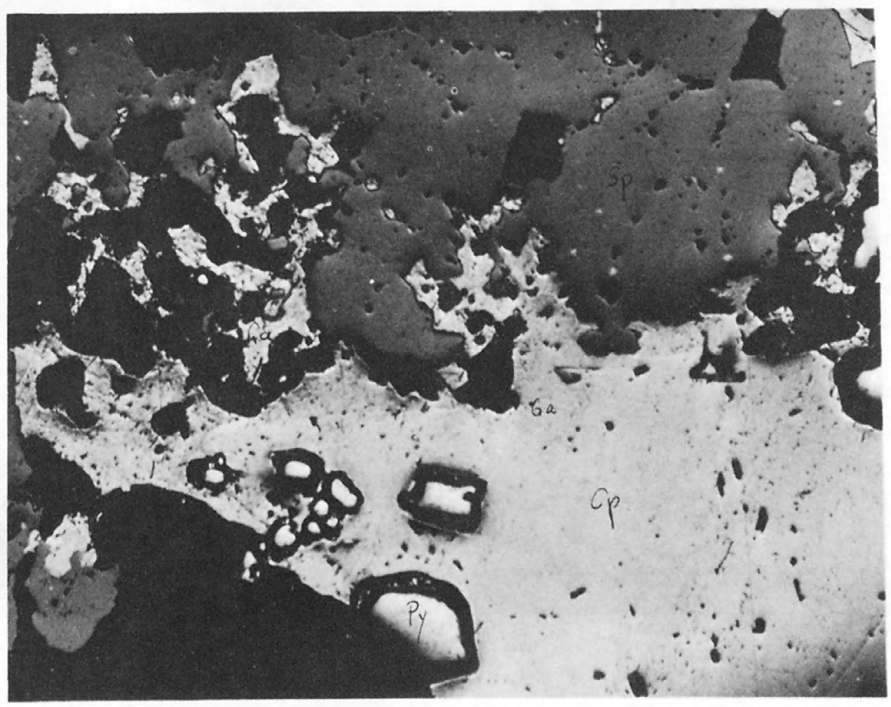
Shows two types of pyrite, intergrown. Sometimes the included pyrite shows rectangular outlines.



W50 - 20 X160 (Polished section 615)

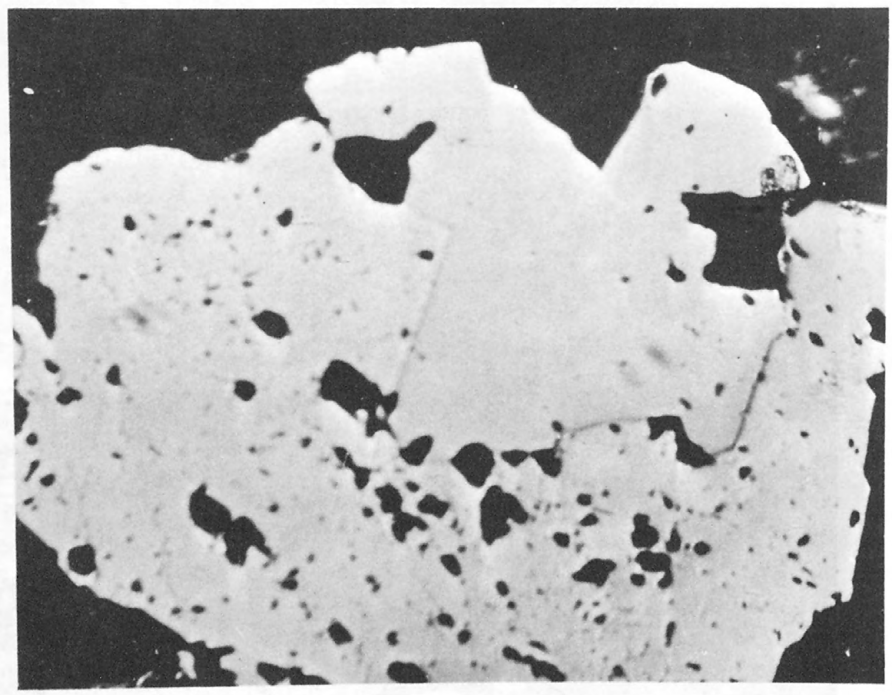
Sphalerite (Sp), chalcopyrite (Cp), and galena (Ga).

Note intergrowth of chalcopyrite and galena, and characteristic cleavage pits (triangular along 111) is galena.



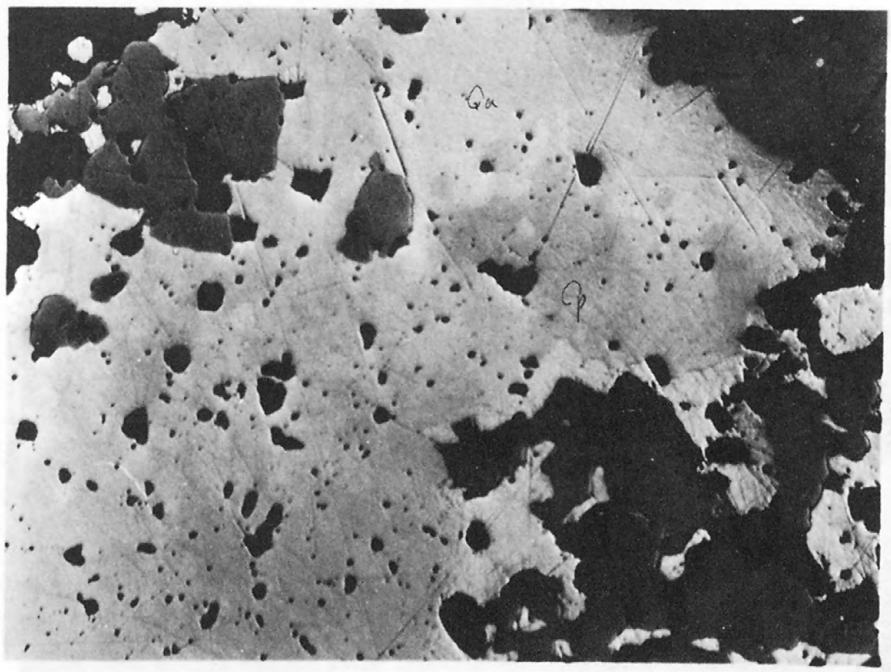
W50 - 20 X160 (Polished section 615)

Chalcopyrite, pyrite, sphalerite, galena.



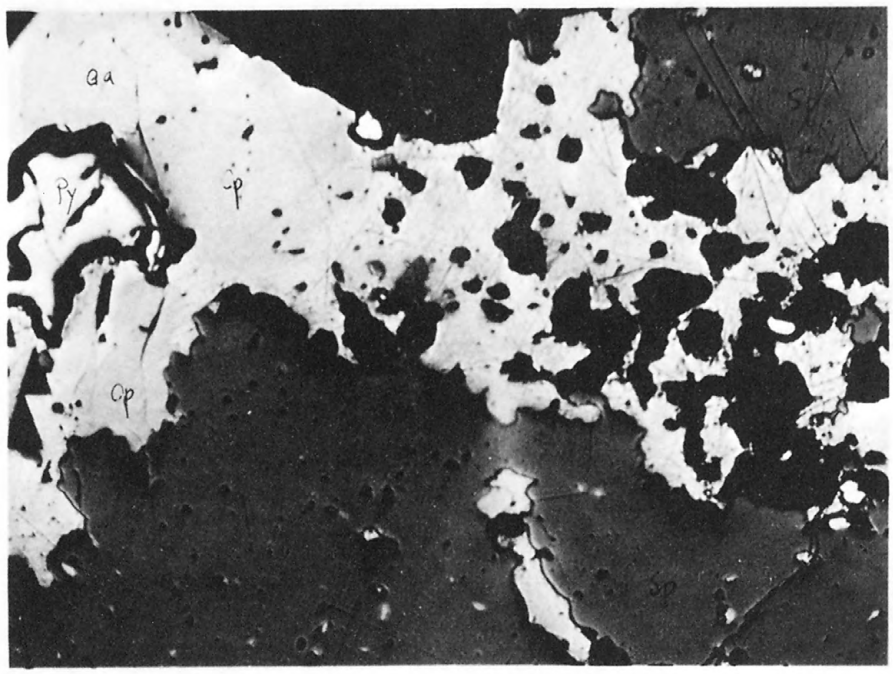
W50 - 20 X160 (Polished section 615)

Shows two types of pyrite intergrown.



W50 - 20 X150 (Polished section 615)

Intergrown chalcopyrite and galena, with sphalerite.



W50 - 20 X150 (Polished section 615)

Intergrown chalcopyrite and galena, with pyrite and sphalerite.

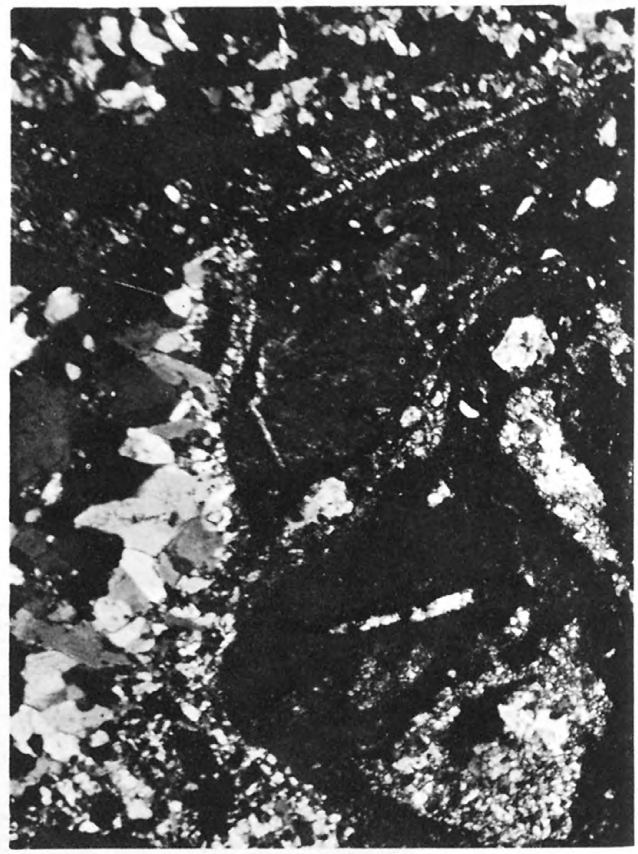
#50 - 24 "Cata mine level 175 S., Crucero 3 Bajo, Frente Norte. Part of Veta Madre, in footwall of old stopes, N 60° W. Gold and silver ore, showing porous structure apparently due to leaching of calcite. This type of ore called 'charasco'." T.F.A.

Polished section 574.

The highly porous rock contains angular dark inclusions of fine grained rock with much pyrite. No ore minerals were noted in the porous rock. Euhedral gypsum crystals are present in some of the pores. Much of the rock is coated with a druse of tiny calcite crystals.

A thin section shows a mixed aggregate, suggesting a breccia, with much flamboyant quartz.

A polished section showed only granular pyrite with traces of sphalerite.

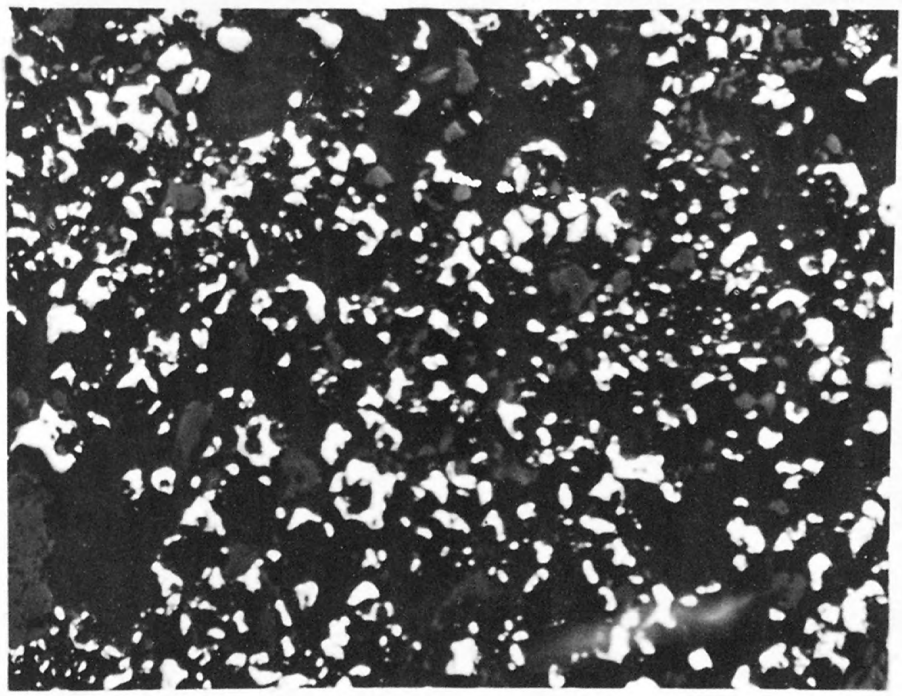


Ordinary light

Crossed nicol

W50 - 24 Thin section X24

Shows inclusion (right) surrounded by flamboyant quartz.
The heterogenous character of the inclusion is seen (tuff fragment?)



W50 - 24 X160 (Polished section 574)

Pyrite in "charasco" type ore. Besides the pyrite, a few small grains of sphalerite are present.

W50 - 27 "Same locality as W50 - 27a. Gold and silver ore, showing chalcopyrite and other sulfides." F.W.

This specimen is a vuggy quartzitic breccia with much carbonate in veinlets and druses.

The ore mineralization is very scanty in this specimen, and no polished section was prepared.

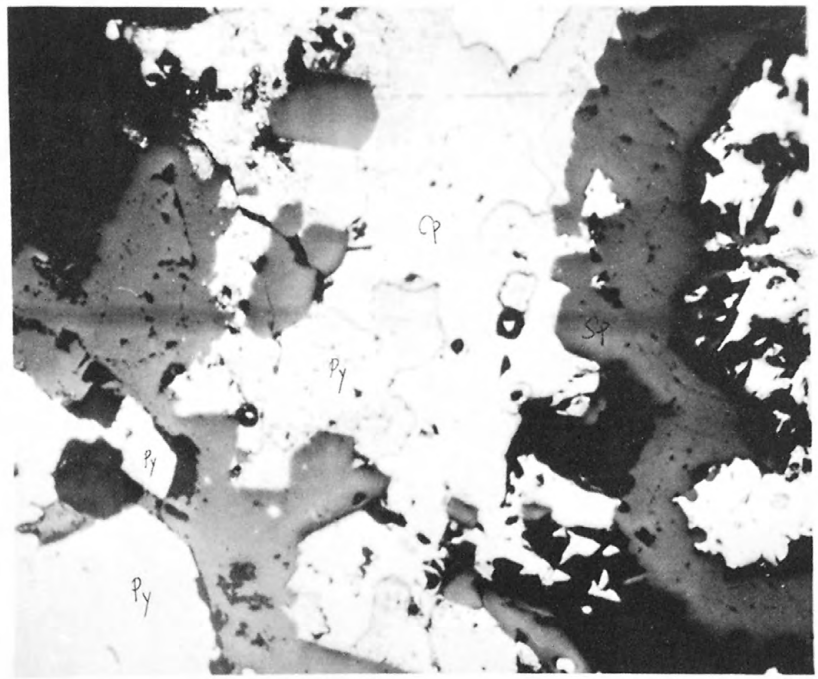
This specimen has black (carbonaceous) fragments; W50 - 28 is definitely carbonaceous; W50 - 29 is in black shale, probably also carbonaceous.

W50 - 27A "Cata mine, level 190 S Chiflon 12. Part of Veta Madre, in footwall of old stopes, N 20° W (same locality as W50 - 27). Gold-silver ore, showing chalcopyrite and other sulfides." I. F.W.

Polished specimens 607 and 609

Sample includes (a) amethystine quartz with dark (country-rock?) inclusions, and abundant chalcopyrite, and (b) siliceous rock with pinkish clay (?) and fossil remains (?), also much mineralized.

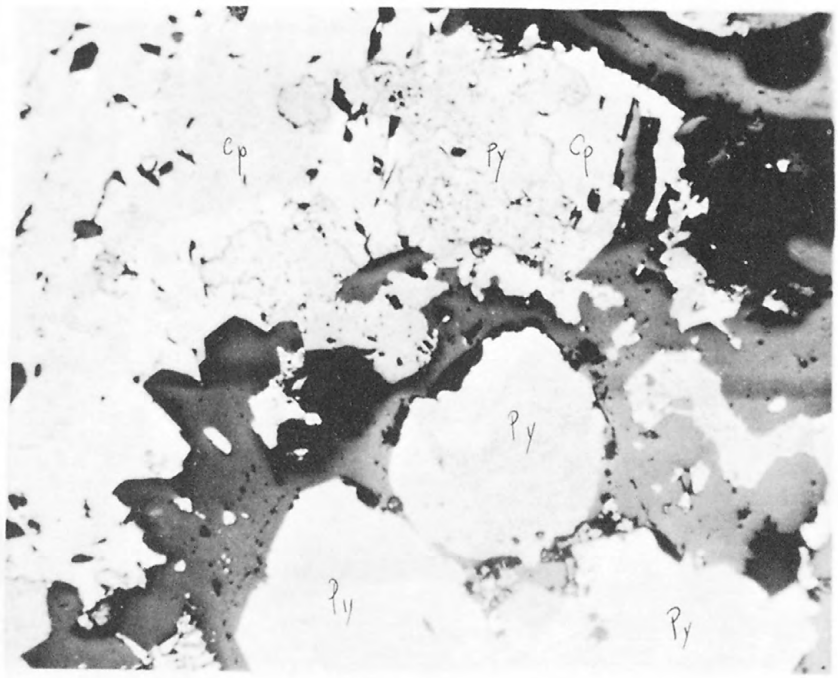
This ore, although containing the same minerals as the other Veta Madre specimens, shows certain differences. Chalcopyrite is more abundant and galena much less. The pyrite is of two distinct types; and marcasite was noted as inclusions in one type.



W50 - 27A X70 (Polished section 609)

Pyrite (two types), chalcopyrite and sphalerite.

Two types of pyrite. One is in sharp fresh subhedral crystals (lower left) usually isolated in the gangue; the other is in rounded porous masses, sometimes enclosing marcasite and almost always included in chalcopyrite.

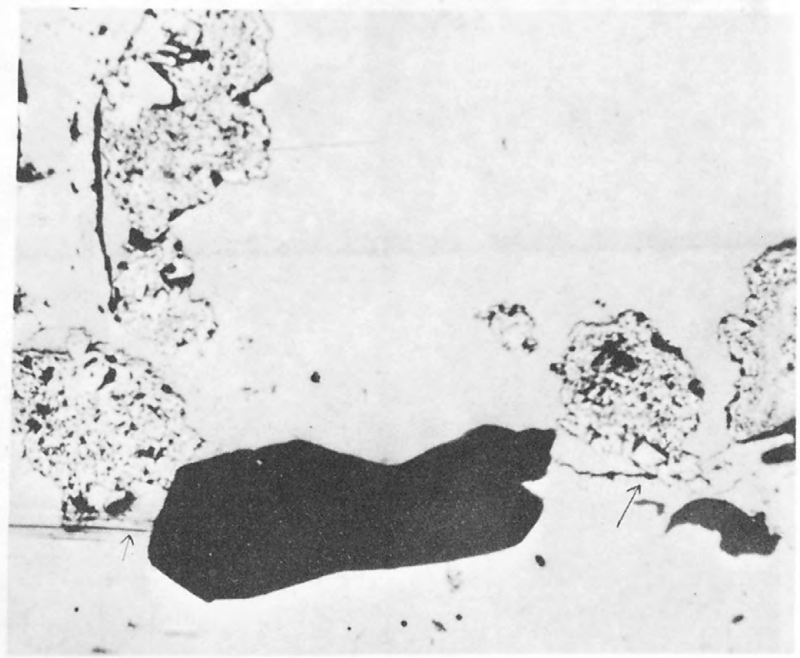


W50 - 27A X70 (Polished section 609)

Pyrite, porous and massive types, with chalcopyrite and sphalerite.

W50 - 27A X350 (Polished section 609)

Shows structure of porous pyrite, with typical radiating openings filled with gangue, also included marcasite (Ma).

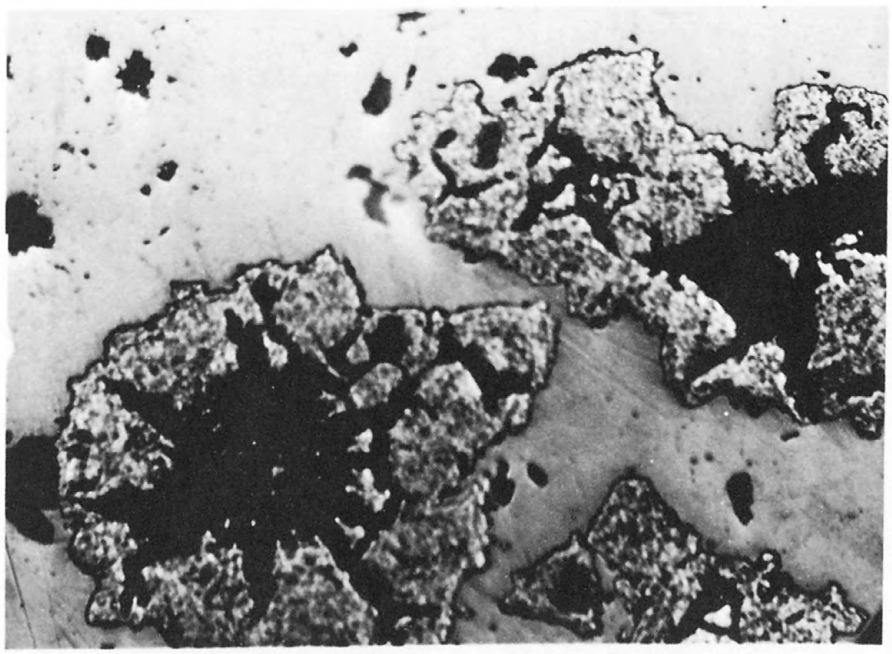


W50 - 27A X350 (Polished section 609)

Porous pyrite with marcasite (indicated by arrows).

W50 - 27A X60 (Polished section 609)

Chalcopyrite (Cp) enclosing variety of pyrite (after marcasite?). Note radial cracks in pyrite.



W50 - 27A X150 (Polished section 609)

Porous pyrite in chalcopyrite. Note radial cracks - shrinkage?

W50 - 28 "Cata mine, level 190 N Crucero 3 Bajo, part of Veta Madre N 20° W. Gold and silver ore, showing manganese oxides." 1 F.W.

(No polished section made)

The specimen is largely coarsely crystalline calcite, with a heavy black coating of powdery material; it is not manganese dioxide; being insoluble in acids, and burning white. Attempt to identify it by x-ray diffraction pattern was inconclusive, the strong lines of quartz (comprising much of the black material) and graphite being very close together. Accordingly, the material is provisionally identified as (graphitic) carbon.

Except for a very few minute pyrite grains, no ore minerals were seen.

W50 - 29 "Cata mine, level 190 S., Crucero Bajo 1. Vein in shale of footwall of Veta Madre, called Veta del Tio Secho. N 30° W. Gold and silver ore, showing prominent band of chalcopyrite adjoining amethystine quartz." 1 F.W.

(Polished section 603)

Amethystine quartz vein cutting dark shale. Coarse chalcopyrite, minor pyrite.

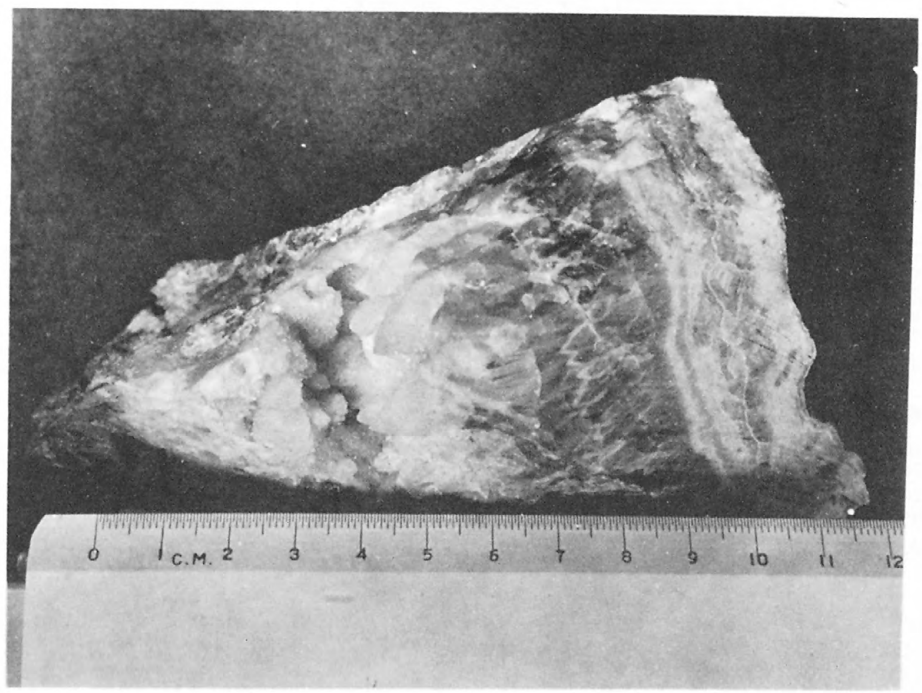
The polished section shows little except coarse chalcopyrite, with scattered pyrite in the shale. The chalcopyrite contains sparingly rounded porous pyrite, very similar to those seen in W50 - 27A.

W50 - 32 "Fragments of wall rock. Rayas mine, level 275 S, Rebaje 315 S, Chiflon 1. Veta Santa Cecilia N 65° W. Does this appear to be evidence of replacement of wall rock by quartz?" I. F. Wilson, 7/14/50.

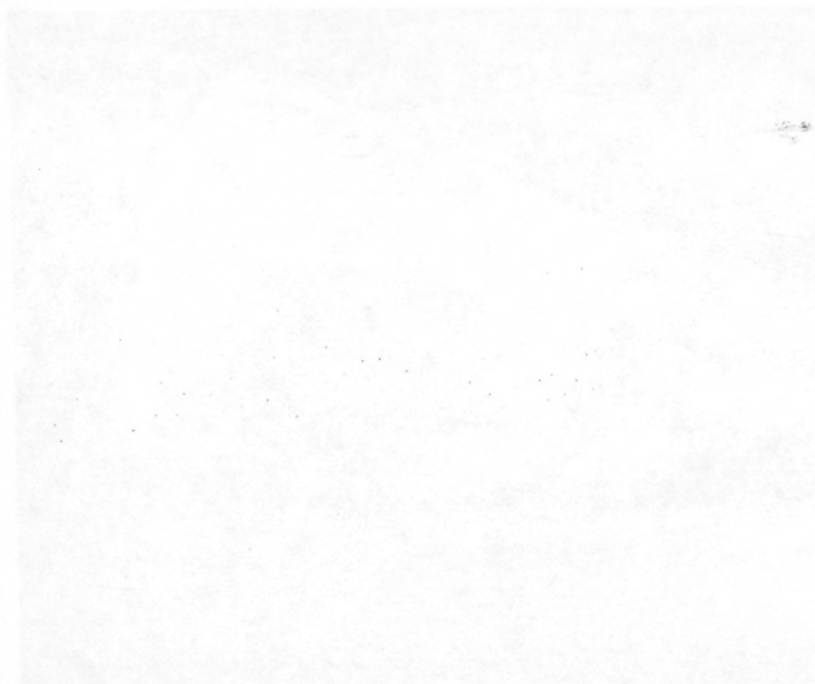
The specimens show (a) a quartz vein 4" wide, banded, with open quartz-lined vugs. The massive part of the vein is amethystine quartz; (b) grey-green wall rock fragments in a matrix of amethystine quartz and marble.

(No polished section - 2 thin sections)

From examination of the thin sections, there has certainly been silicification (i.e. replacement) of wall rock. There is also ample evidence that the "comb" quartz crystals grew in open cavities (fissures). Doubtless both processes could take place, concurrently.

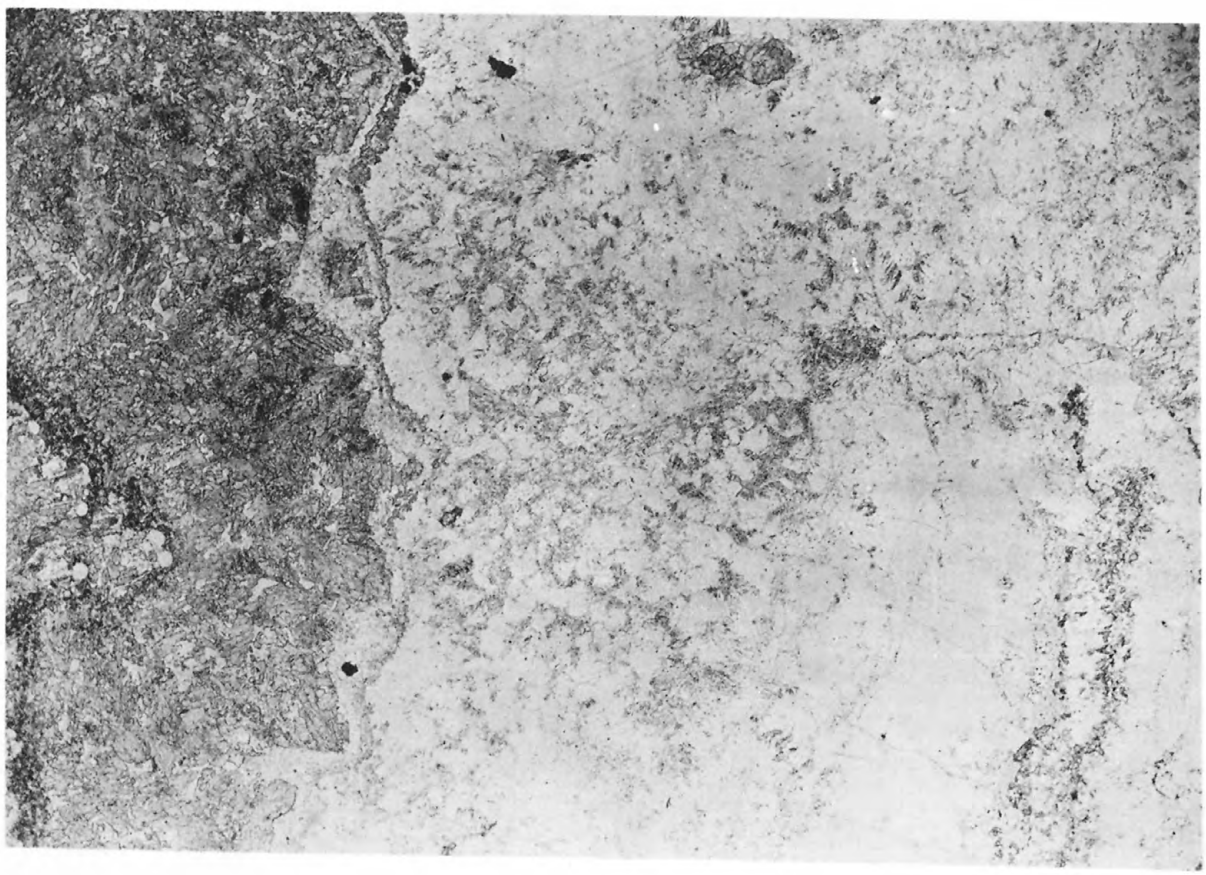


W50 - 32 Typical vuggy quartz, showing banding and amethystine quartz (darker zone). The left and right ends of the specimen are wall rock. A little pyrite is disseminated in the gray-green wall rock, but the quartz appears to be barren.



In this section the fragments of siliceous porphyritic rock, with occasional sodic plagioclase phenocrysts, and much euhedral pyrite, are surrounded and often merge into a coarsely crystallized (flamboyant) quartz matrix. The smaller quartz veinlets separating the brecciated wall rock often have alkalic feldspar accompanying the quartz. The coarsest quartz crystals show strong zoning. Pyrite also occurs in the quartz, indicating that it was introduced during the brecciation.

A second thin section across the quartz-vein shows no wall rock, but abundant rhombohedral carbonate.

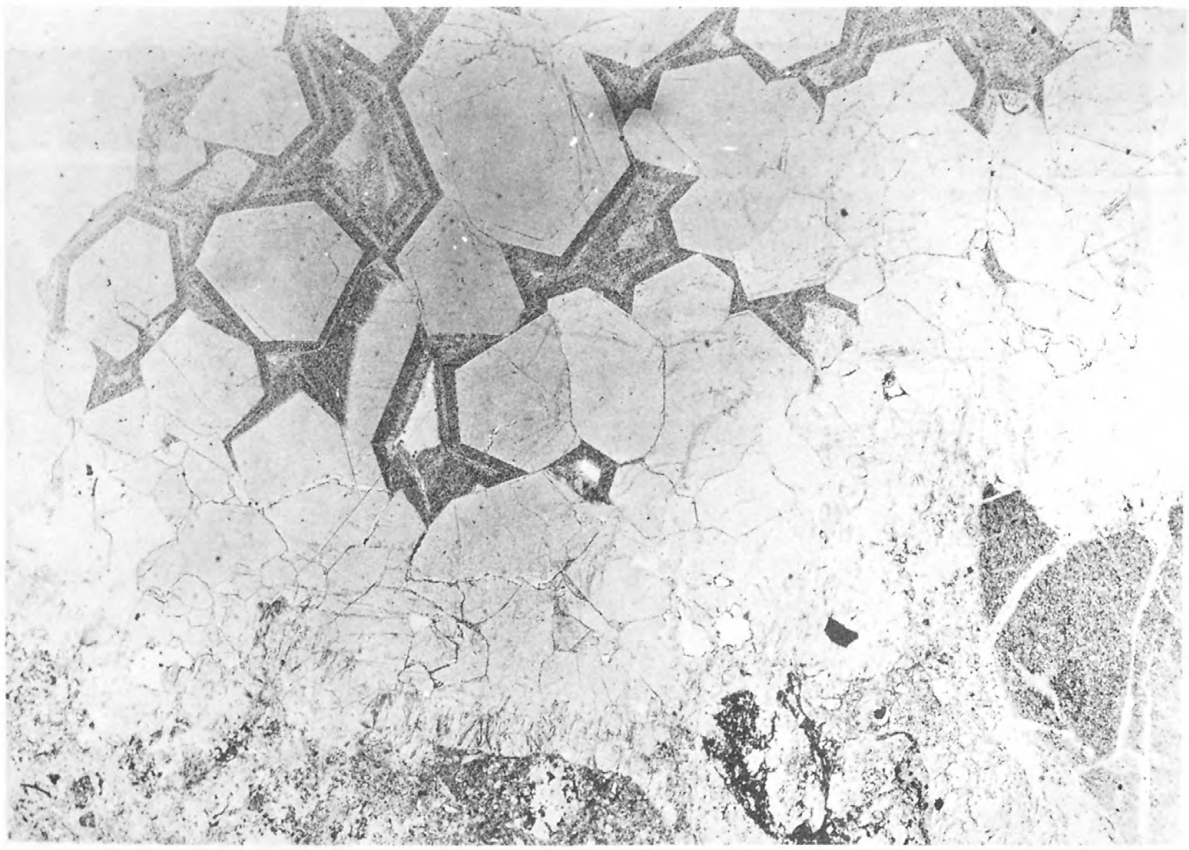


W50 - 32 (Thin section) X17 ordinary light

Quartz vein, with rhombohedral carbonate (left).

W50 - 32 (Thin section) X12 crossed nicol

(Same field as preceding picture)



W50 - 32 (Thin section) X12

Wall rock fragments, strongly silicified, on top.
Euhedral quartz crystals, strongly zoned, with further zoning on interestitial later quartz.

W50 - 36 "Rayas mine, level 220 S Rebaje 14 Los Pozos vein, in H.W. of main vein N 60° W. Gold and silver ore, showing dark bands of silver sulfides, cut by a later veinlet of pyrite (crosscutting relation is very evident in mine)". I.F.W.

(Polished sections 586, 618, 621)

The massive quartzite specimen is somewhat drusy, and here and there is amethystine. It contains a conspicuous pyrite-marcasite vein, several millimeters thick, and several thinner dark (sphalerite, etc.) veins of sulfides. A fibrous yellowish mineral associated with these veins was determined at chlorite (X-ray film 5483). The elongation is (+), the refractive indices close to 1.57, birefringence being low. Fibrous chlorites are not so common as platy types.

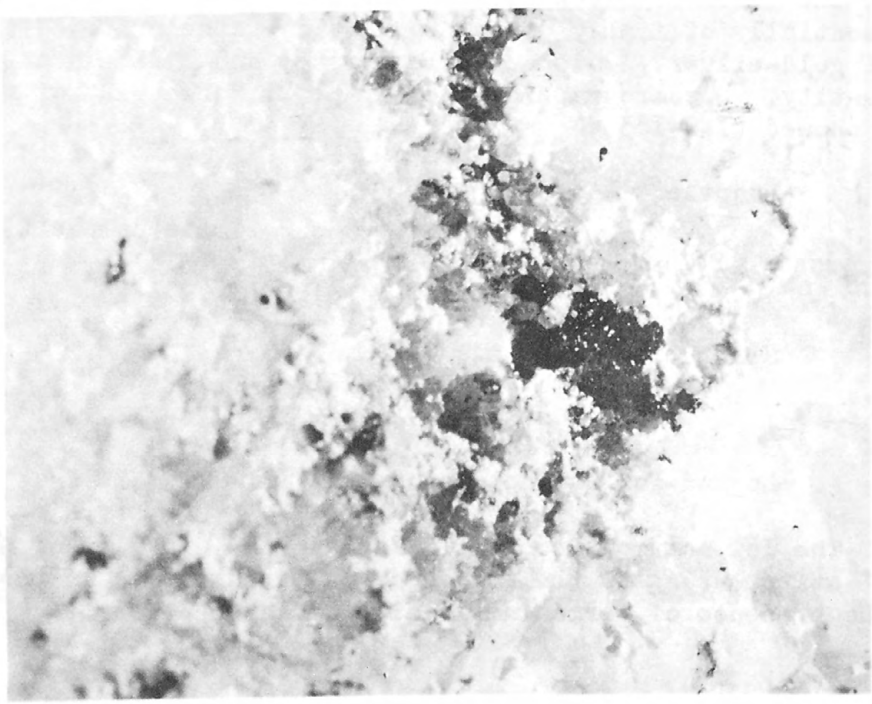
Under low magnification, the quartz is seen to be deeply etched and corroded, and here the chlorite is abundant. In this etched quartz argyrodite is found in minute black crystalline masses; identified by J. M. Axelrod (X-ray films 5484 and 5486) and E. L. Hufschmidt (Spectrographic report IWS-183). No tin was detected in the argyrodite.

The "vein of black silver minerals", about 1/4 inch wide, consists essentially of finely disseminated black sphalerite, with numerous flakes of gold-silver. Galena, chalcopyrite, and pyrite are present in minor quantity. Spectrographic study by E. L. Hufschmidt of the vein material showed (IWS-183):

Major elements	Ag	26	(approximate composition)
	Zn	22	
	Pb	2	
	Cu	1	
Minor elements	Au	0.X%	
	Sb, Cd	.0X%	
	Sn, Co, Ge	.00X%	

Looked for but not found - Pt, Bi, Tl, Ni, In.

The low antimony content is noteworthy, in view of Wandke and Martinez' statement as to the abundance of tetrahedrite in the Guanajuato ores. The presence of germanium is also of interest.

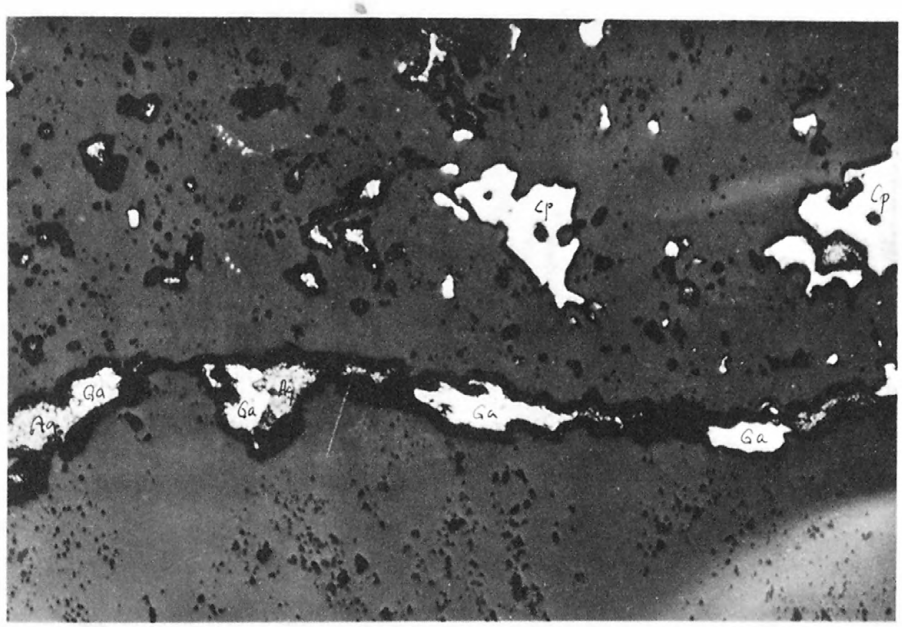


W50 - 36 X20

Argyrodite on drusy quartz with fibrous chlorite.

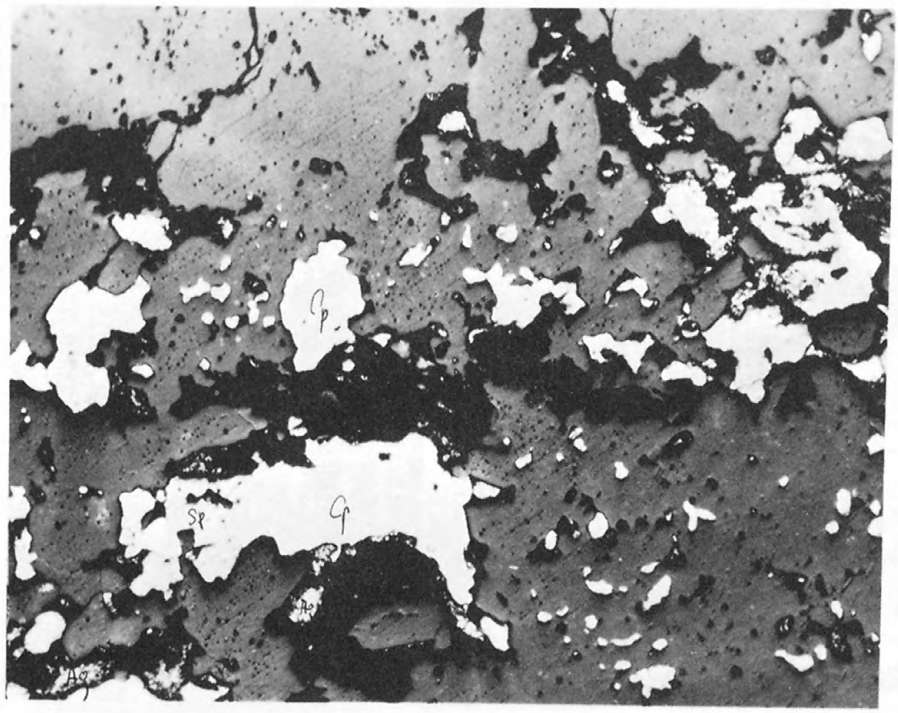
W50 - 36 X6

Argyrodite on quartz.



W50 - 36 (Polished section 586) X150

Argentite with galena. Chalcopyrite (edge, right)



W50 - 36 (Polished section 586) X150

Chalcopyrite (Cp), Sphalerite (Sp), Argentite (Ag)

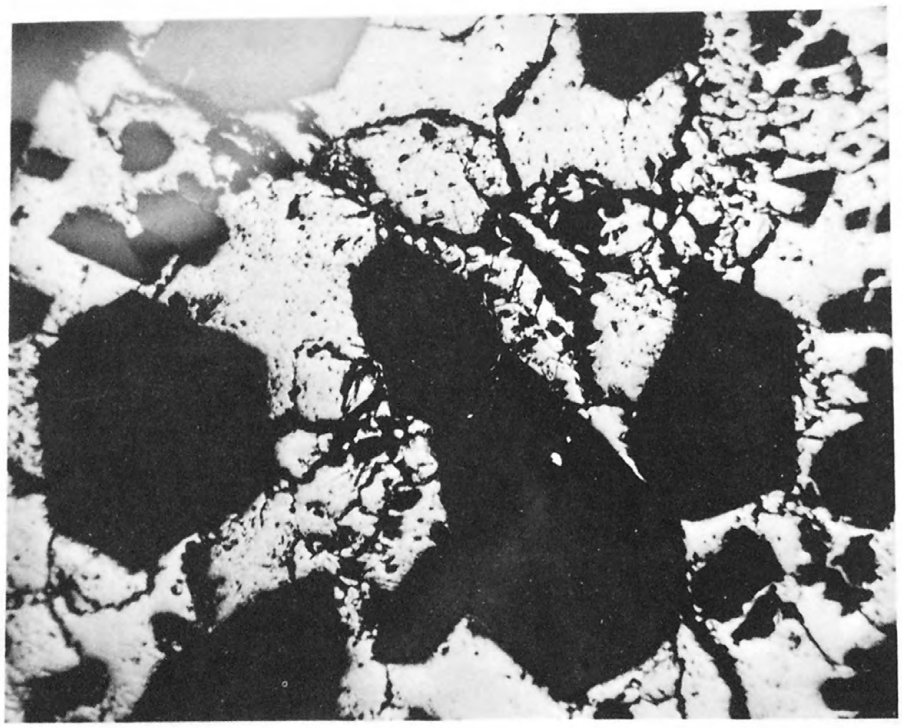
Ordinary light Crossed nicol

W50 - 36 (Polished section 621) X150

Much of the solid "pyrite" is marcasite, as shown above (note lamellar twinning).

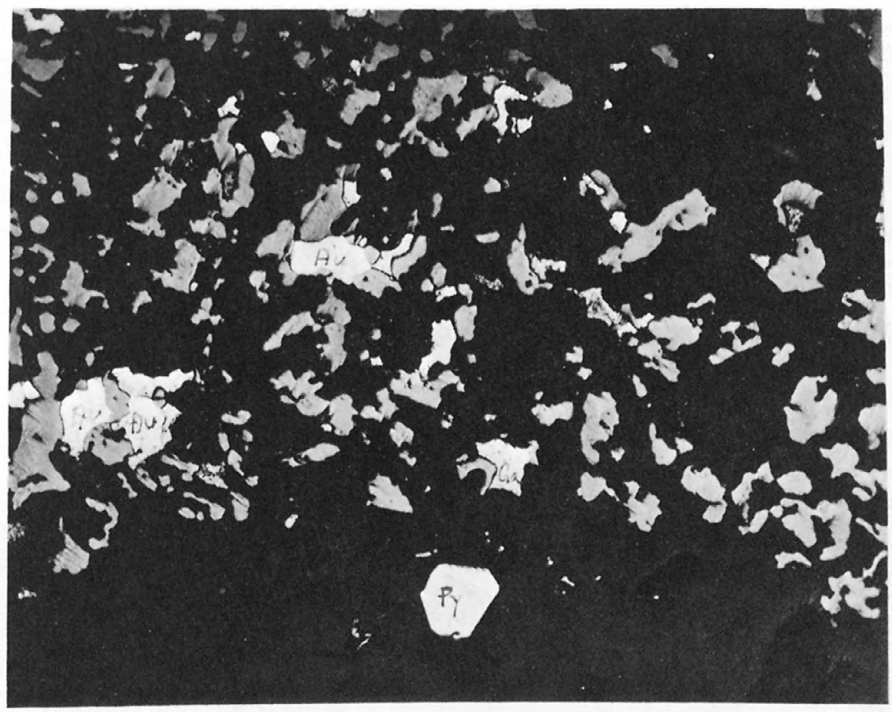
W50 - 36 X150 (Polished section 586)

Galena and argentite, etc. The black areas may indicate a very soft silver mineral (argentite?) which the grinding process has gouged out.



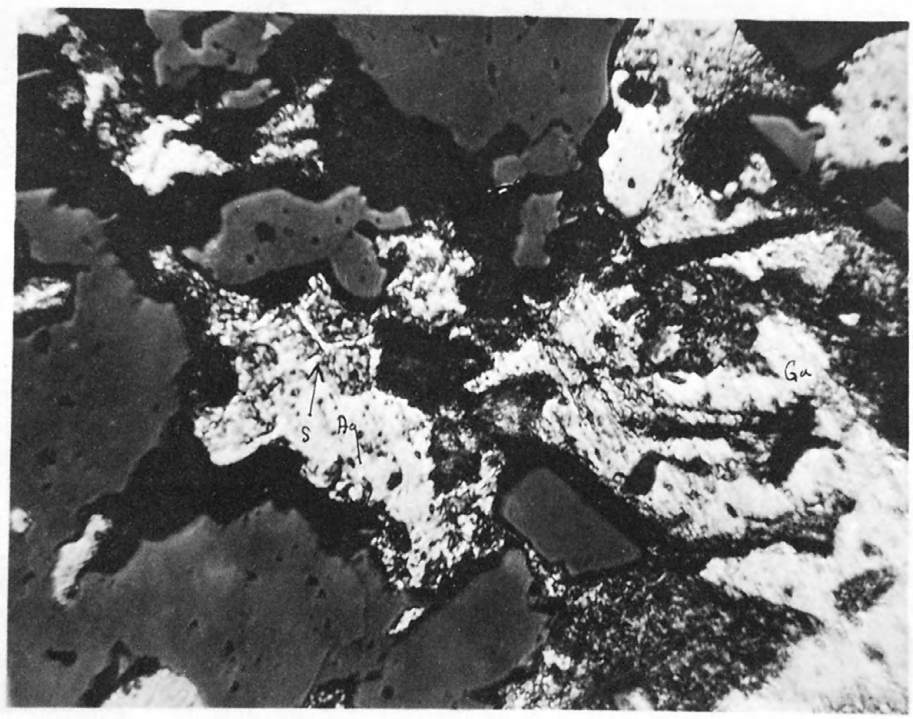
W50 - 36 X150 (Polished section 621)

Pyrite (with some marcasite) forming vein in quartzite. Note euhedral quartz (gray).



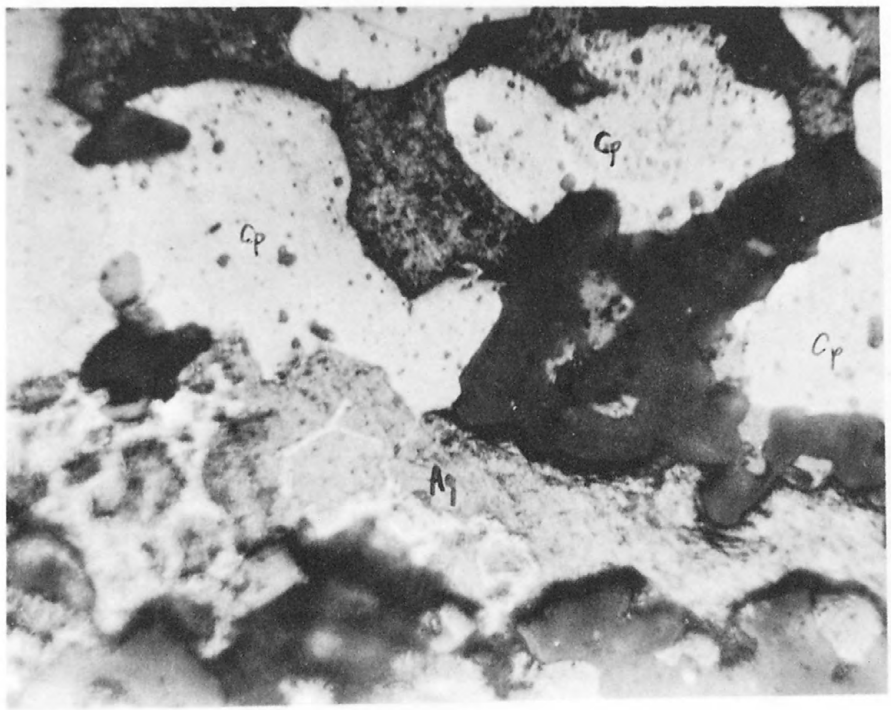
W50 - 36 X150 (Polished surface 618)

Gold (Au), Pyrite (Py), Galena (Ga)
The abundant grey patches are sphalerite, with occasional bright small areas of galena.



W50 - 36 X375 (Polished section 586)

Galena with argentite and wire silver (?)



W50 - 36 X375 (Polished section 586)

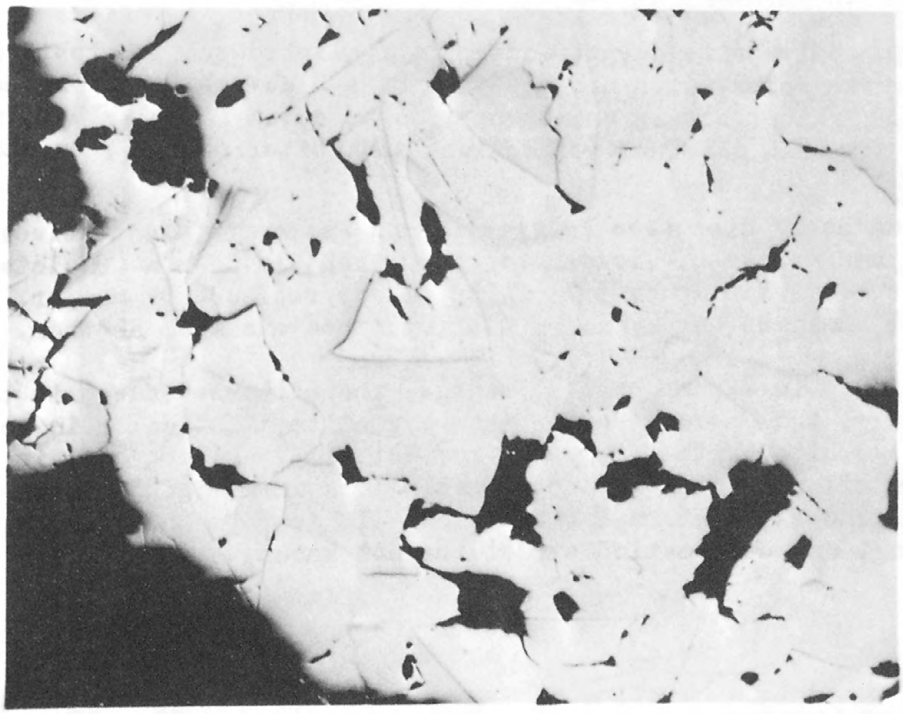
Chalcopyrite with argentite and wire silver (?)

W50 - 37A "Rayas mine, level 220 S Rebaje 14, Frente Sur Veta los Pozos HW of Veta Madre. Porous quartz and crystalline marcasite." I.F.W.

(Polished section 588)

A polished section shows only marcasite with some pyrite, having the relations shown in the figure.

The pyrite is distinctly reddish against the marcasite, and is isotropic, whereas the marcasite shows strong anisotropy and polysynthetic twinning. The pyrite also is harder, showing strong relief.



W50 - 37A X150 (Polished section 588)

Marcasite with pyrite.

W50 - 39 "Rayas mine, level 275 S, Chiflon 2, San Cipriano vein, N 85° W. Gold and silver ore, showing crystals of sulfides." I.F.W.

Polished sections 589 and 592

This specimen is pyritized wall rock cut by quartz-carbonate veins, with sphalerite, etc., in an inch-wide band. Polybasite (X-ray film 5283) was noted in the vuggy quartz; also in polished section 589.

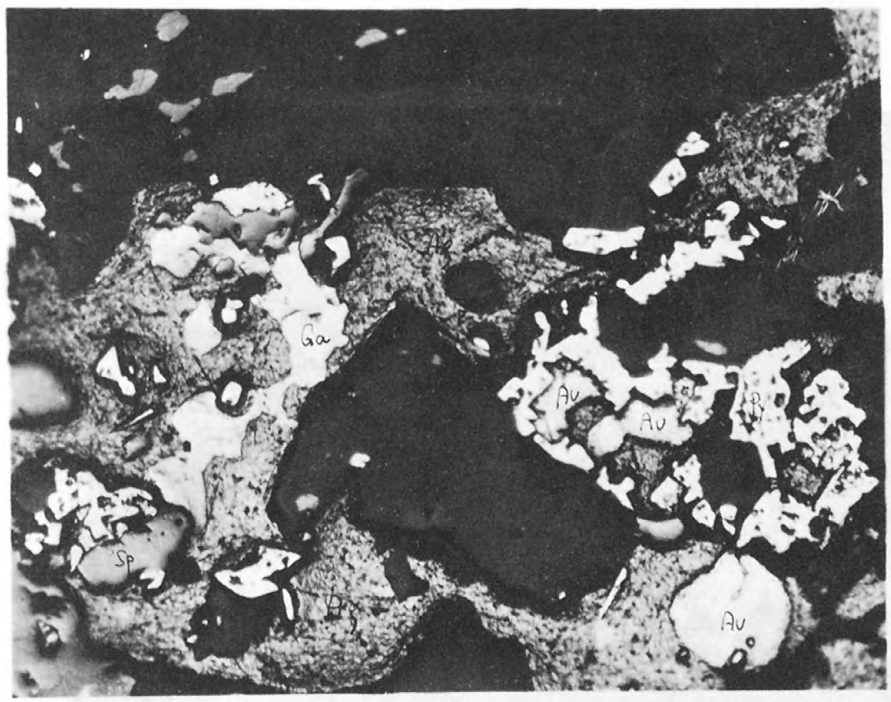
Polished section 592 shows abundant argentite with free gold, with pyrite, chalcopyrite, galena, and sphalerite. Paragenetic relationships are rather clearly shown, as illustrated below.

Polished section 589 is the only one of the Guanajuato suite in which polybasite was recognized. It should be emphasized that the identification of this mineral rests primarily on X-ray data from relatively large crystals having similar relationships, i.e. on quartz druses - as that shown in the polished section. It is not altogether impossible, though unlikely, that the mineral seen in the polished section may be other than that recognized in the hand specimen.

The polybasite identification in polished section rests on: the dull grey white color, with a suggestion of a blue-gray tint; rather low reflectivity; rather strong anisotropy; vague cubic (?) cleavage, weak but observable deep red internal reflection, and better polish than shown by argentite.

Ramdohr discusses Polybasite and Pearceite, respectively $Ag_{16}Sb_2S_{11}$ and $Ag_{16}As_2S_{11}$ together: they probably form a complete isomorphous series, with up to 30% of the silver replaced by copper. Microscopically, they are hardly to be distinguished one from another.

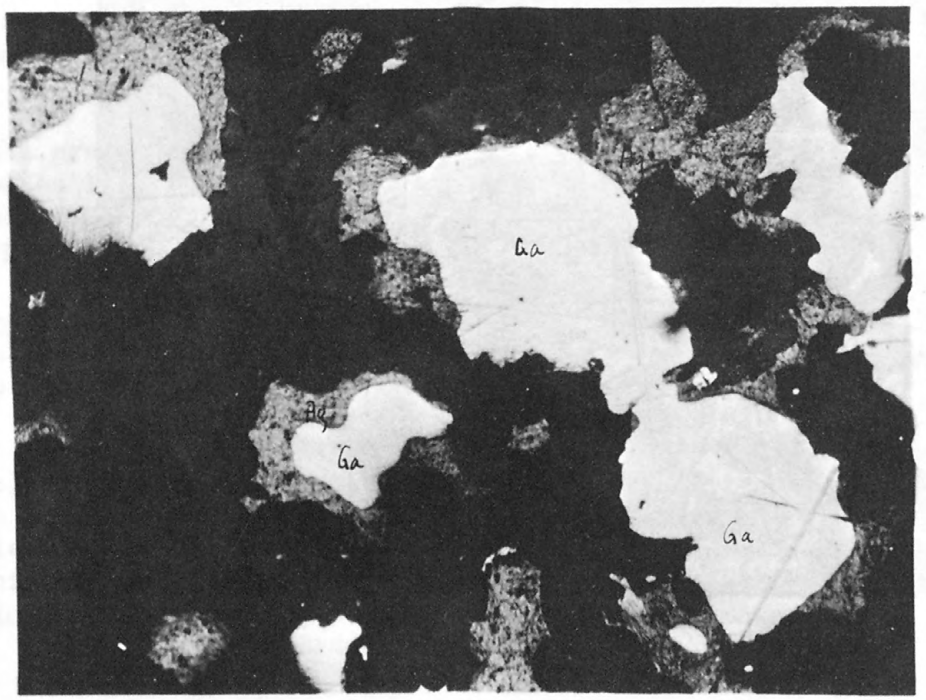
There is a poor basal cleavage; the softness causes it to polish poorly, though much better than argentite. The color in section is dull grey-white, with fairly low reflectivity. Pleochroism is barely visible; in oil varies from faintly green to a dark violet-bluish gray. Anisotropy is weak. Internal reflection, if present, rather weak. Twinning, zoning, and deformation structures not known.



W50 - 39 X150 (Polished section 592)

Pyrite (Py), Gold (Au), Chalcopyrite (Cp), Argentite (Ag), Sphalerite (Sp), and Galena (Ga)

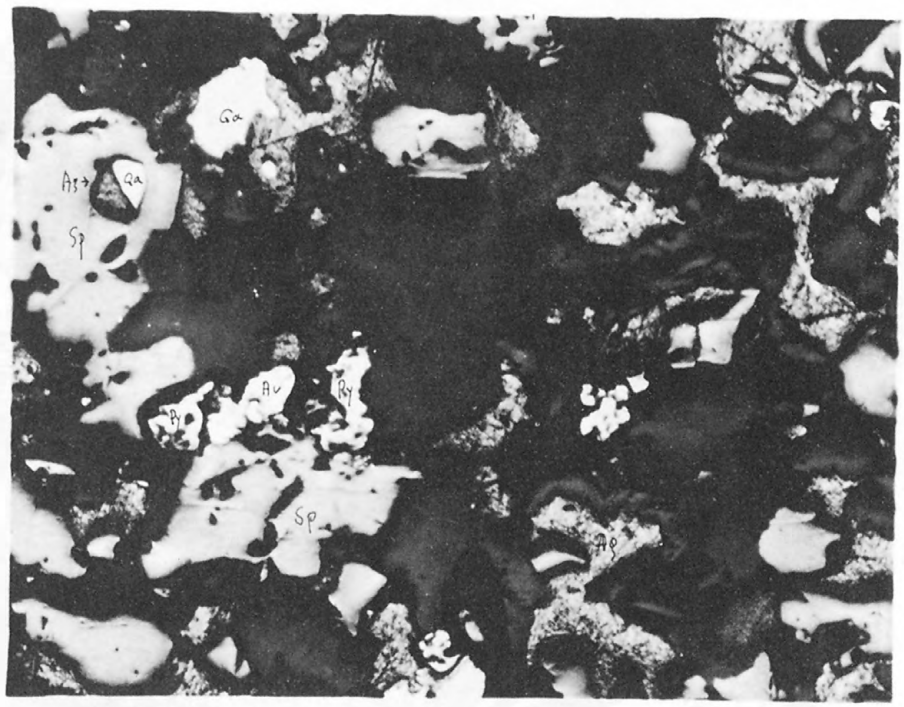
The galena (left center), intergrown with chalcopyrite, shows replacement by argentite. The gold (lower right) is moulded against, and encloses, pyrite. The argentite is moulded against quartz crystals.



W50 - 39 X150 (Polished section 592)

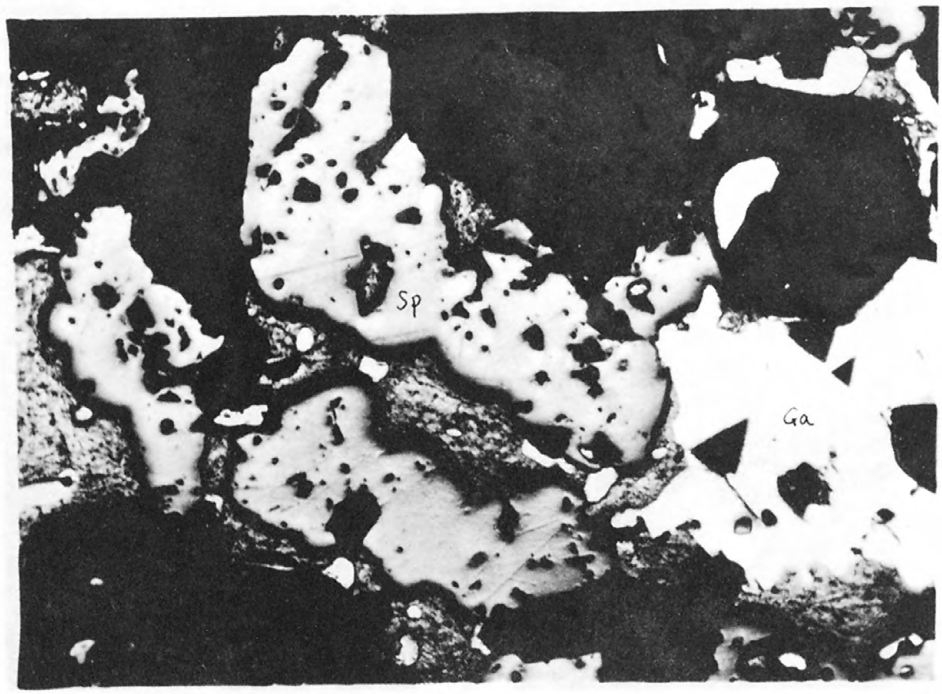
Replacement of galena (Ga) by argentite (Ag)

The galena is surrounded by argentite and shows rounded surfaces against the latter. Surrounding both is sphalerite.



W50 - 39 X90 (Polished section 592)

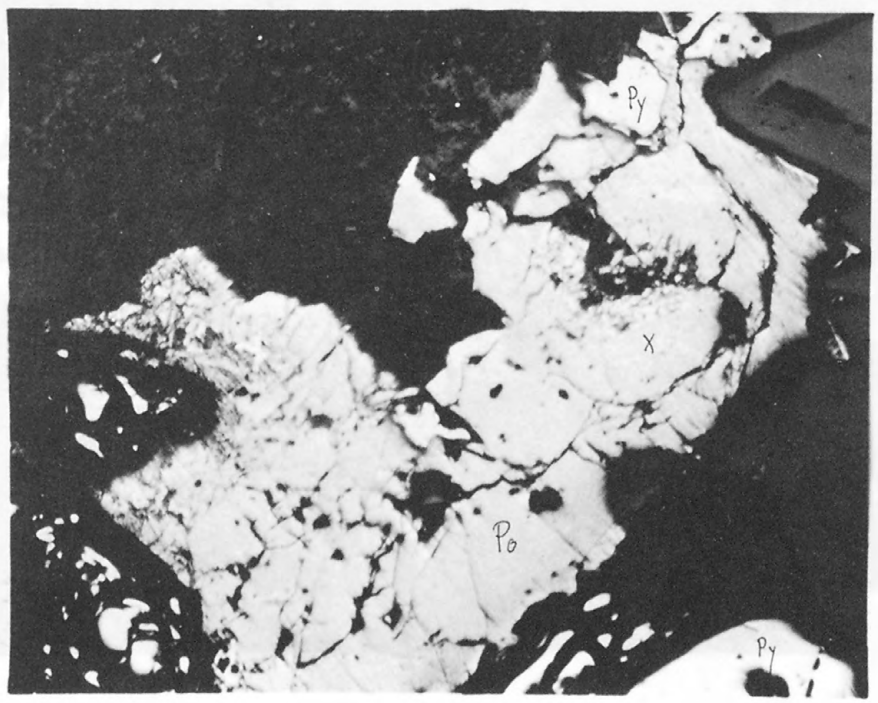
Gold, argentite, sphalerite, galena, pyrite.



W50 - 39 X90 (Polished section 592)

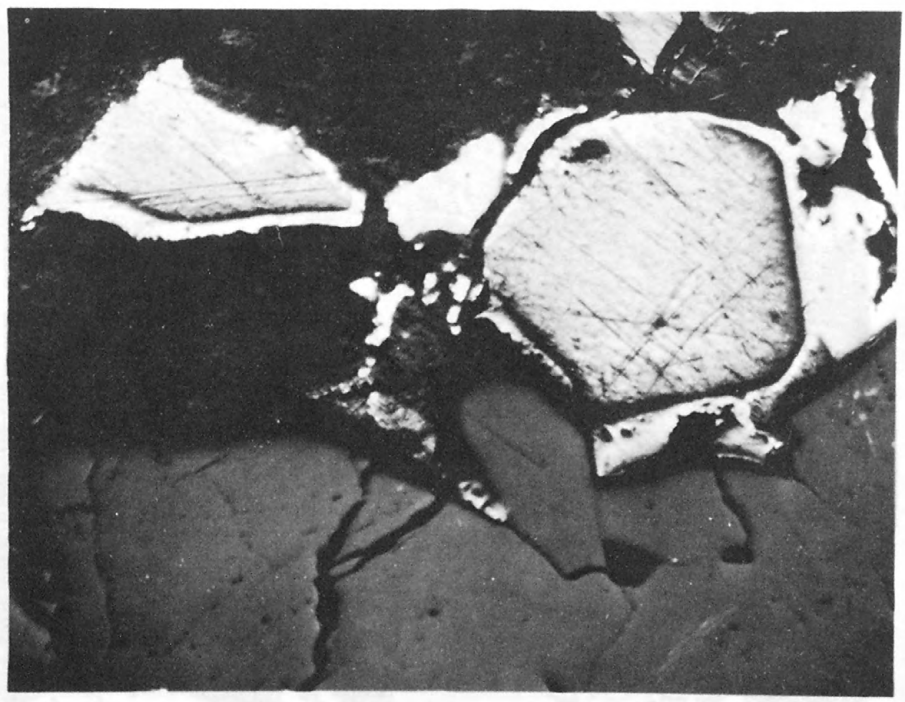
Galena, sphalerite, argentite

Argentite replacing sphalerite.



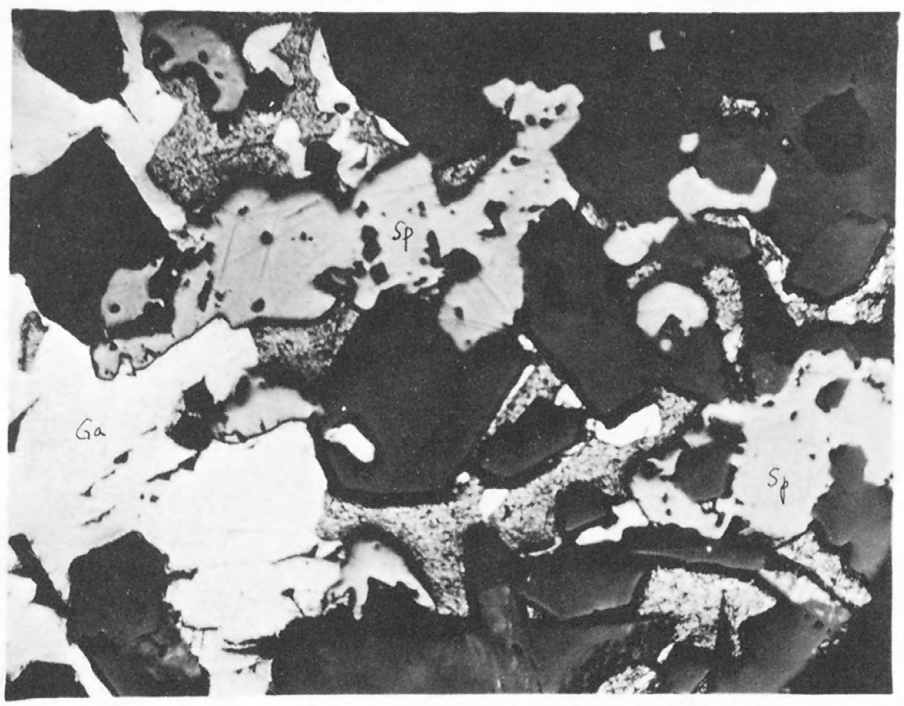
W50 - 39 X60 (Polished section 589)

Polybasite (Po) with pyrite, coating quartz in vug. At X exsolved galena (?) may be seen.



W50 - 39 X60 (Polished section 589)

Polybasite with chalcopyrite ~~iron.~~ Yim



W50 - 39 X150 (Polished section 592)

Argentite, galena, sphalerite.

Note unreplaced remnants of galena in argentite.

W50 - 39? X150 (Polished section 592?)

Galena (moulded against quartz).

Argentite (upper left, lower right) replacing galena.

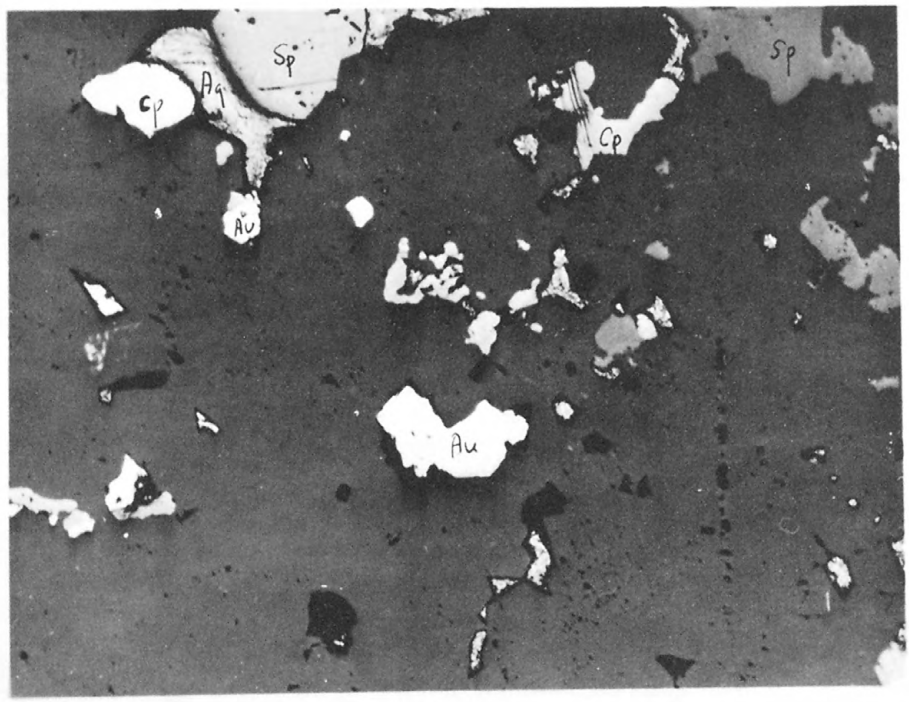
WJO-40 Rayas Mine level 275 S Chiflon 43DS Vein in HW of Veta Madre - possibly Los Pozos vein.

"Gold and silver ore, showing dark bands of sulfides paralleling quartz, also pyrite scattered through wall rock." I.F.W.

Coarse quartz with brownish green wall rock fragments.

Polished Section 606

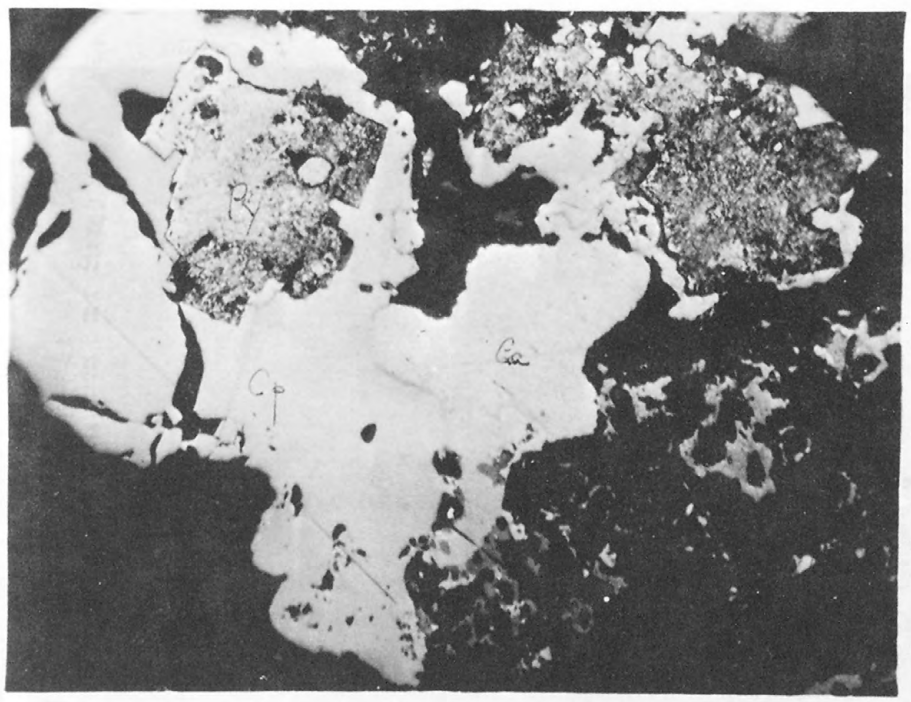
The section shows the usual fine-grained aggregate of pyrite, chalcopyrite, sphalerite, galena, argentite and free gold.



WJD-40 X150 (Polished Section 606)

Gold (Au) Chalcopyrite (Cp)

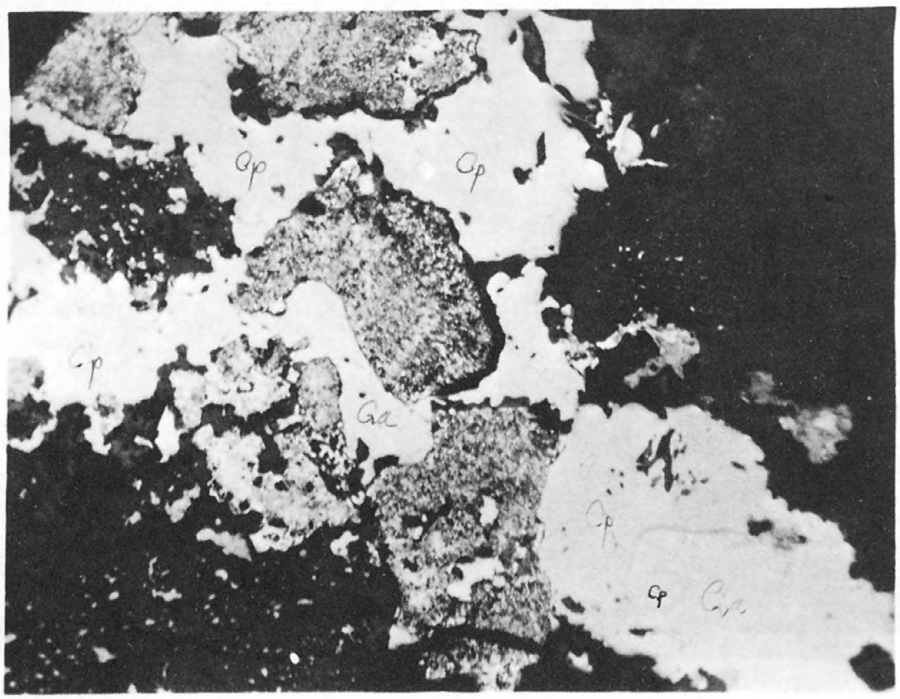
Sphalerite (Sp) Argentite (Ag)



W50-40 X150 Polished section 606

Chalcopyrite galena pyrite

Note porous character of pyrite enclosed by chalcopyrite. The lower right is quartz, etc. with disseminated argentite.



W50-40 X150 Polished section 606

Galena chalcopyrite pyrite

Note porous pyrite. Also chalcopyrite replaced by galena (lower right).

W50-41 Cata Mine, level 190S Chiflon 12 Part of Veta Madre in footwall of old stopes.

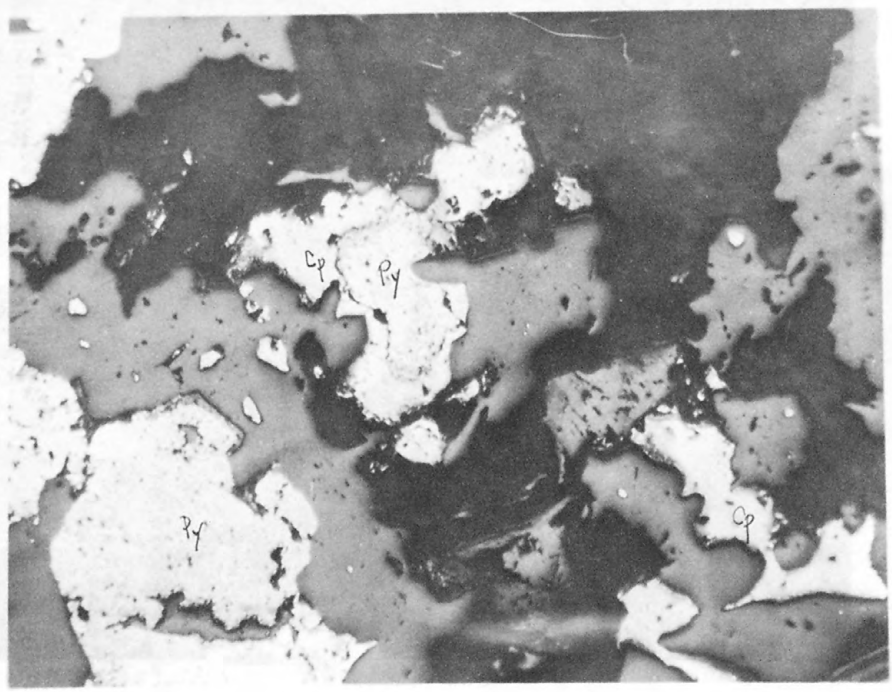
"Gold and silver ore showing abundant sulfides in wall rock, adjoined by veinlet of xline amethystine quartz." I.F.W.

"Polished specimen 604"

The two specimens are respectively largely coarsely crystallized amethystine quartz, and (presumably) the mineralized siliceous wall rock. A polished section of the latter shows the usual sphalerite, chalcoprite, galena, and pyrite and also polybasite and gold.

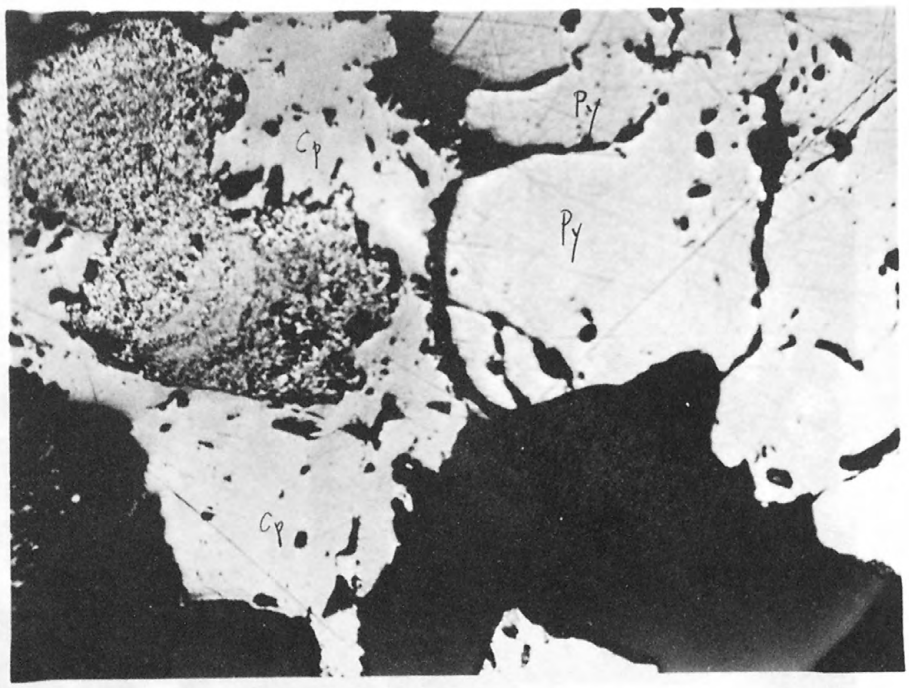
W50-41 X160 Polished section 604

Galena polybasite sphalerite



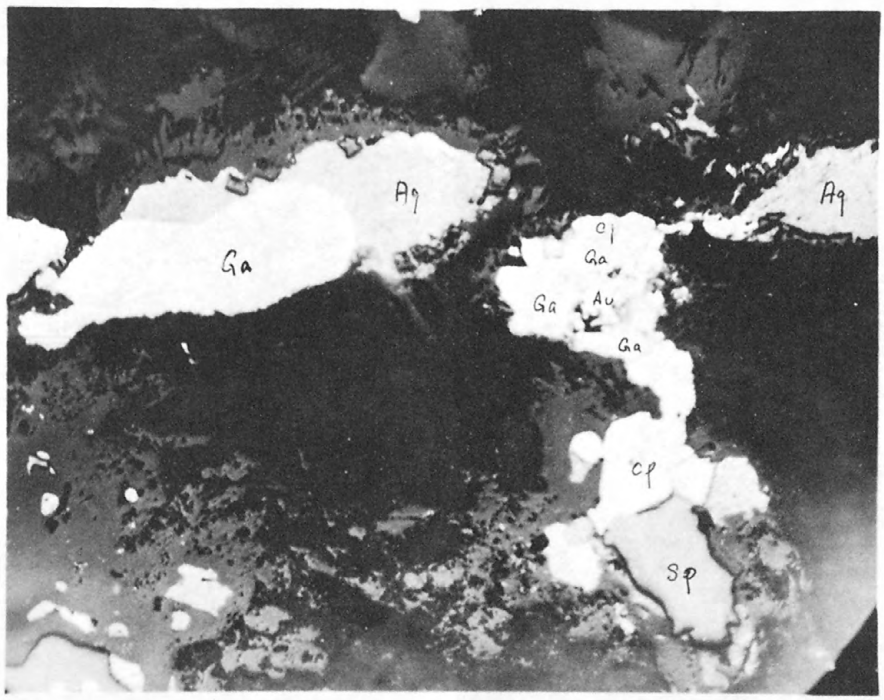
W50-41 X160 Polished section 604

Pyrite (two types) chalcopyrite



W50-41 X150 Polished section 604

Pyrite (pouous, enclosed by chalcopyrite) and erdinary pyrite (right side).



W50-41 X150 Polished section 604

Gold, argentite, galena, sphalerite, chalcopyrite, and pyrite

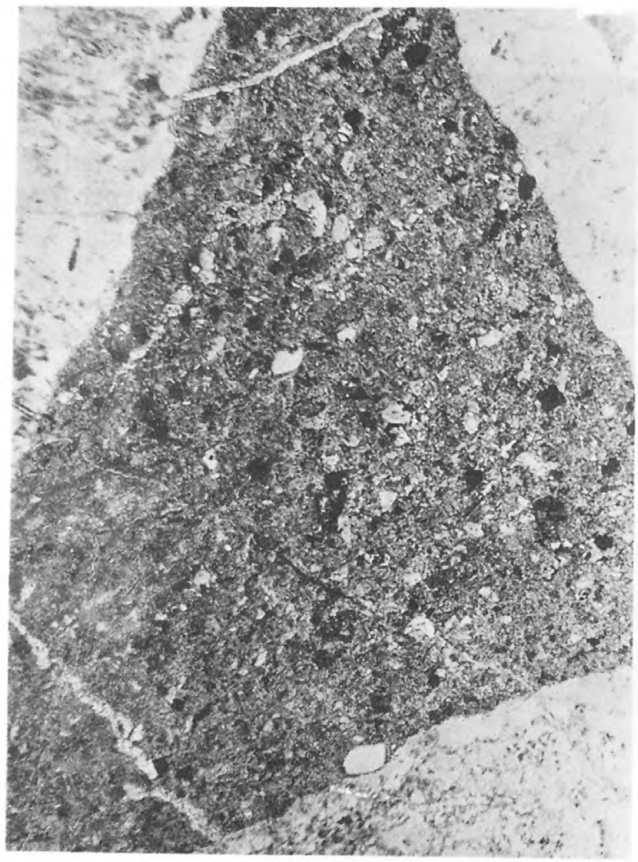
W50-42 Promontoris Mine, level 35, stope co-ordinates 3195S 2038E.
Part of main vein of Veta Madre.

"Gold and silver ore, showing numerous patches of dark sulfides." I.F.M.

Polished section 613

Specimen is largely amethystine quartz, bordered with dark aggregates, in which only occasional pyrite specks are visible. A thin section shows flamboyant quartz surrounding sharply defined angular tuff (?) fragments.

In the polished section, scanty scattered grains of pyrite, chalcopyrite, sphalerite and galena were noted. In this particular specimen, the mineralization is much scantier than in the others.



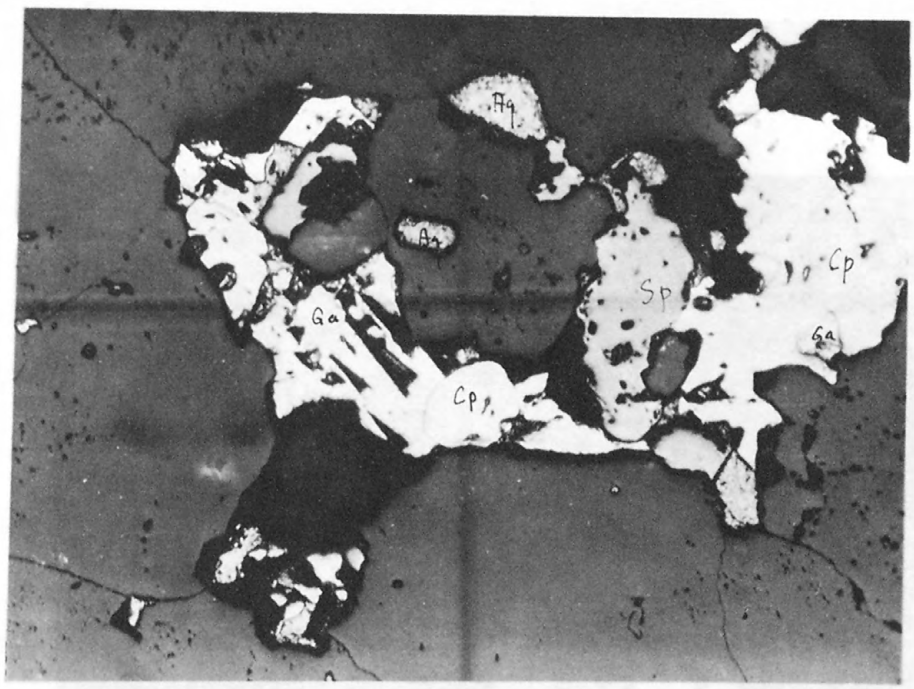
Ordinary light X24

W50-42 Tuff (?) fragment enclosed by flamboyant quartz. Note pyrite cubes in tuff (?) fragment.

"W50-43 Promontoris Mine, level 75N Frente Norte in HW - part of main vein at Veta Madre." I.F.W.

Polished sections 602 - 608

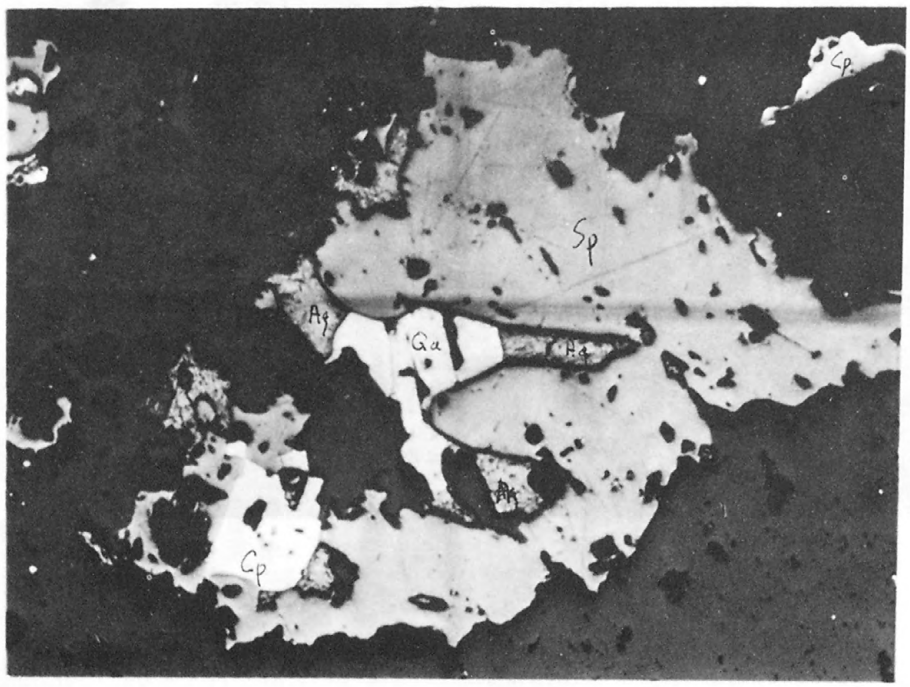
The specimen is the usual siliceous (in part amethystine) rock. It is well-banded with several 1/2 inch dark sulfide-rich bands.



W50-43 X160 (polished section 602)

Chalcopyrite, galena, sphalerite, argentite

The galena is in large enough grains to show the rarely-seen diagnostic cubic cleavage.

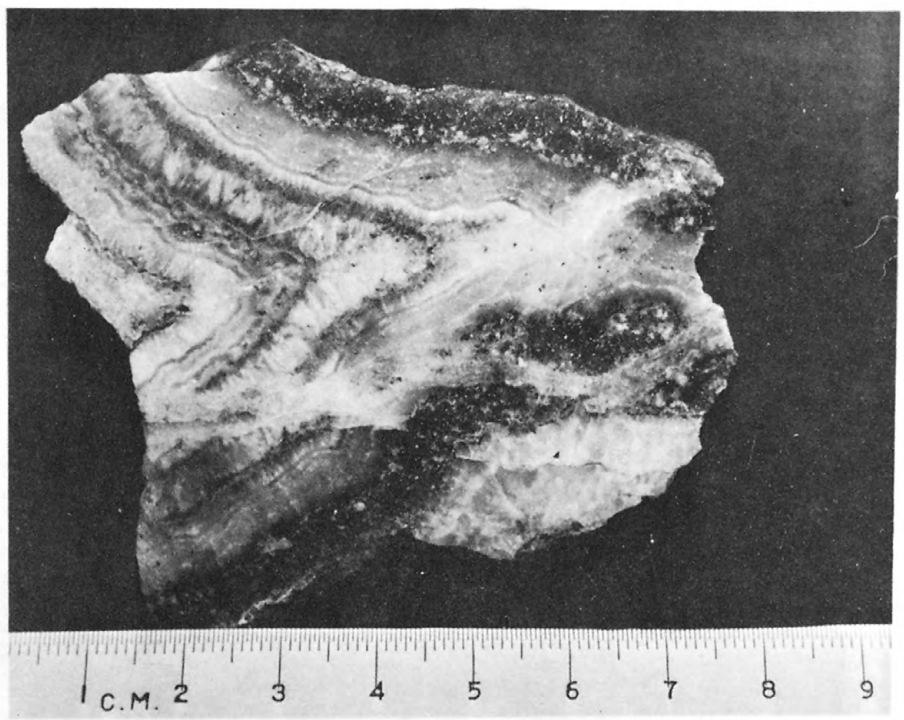


W50-43 X160 (polished section 602)

Argentite (Ag), Sphalerite (Sp) Galena (Ga) Chalcopyrite (Cp)

Galena shows cleavage.

WJO-43 Vug with quartz crystals and argentite (X-ray film).



WJO-43 Polished face of banded quartz, showing sulfide-rich areas (dark) and comb structure is quartz. Microscopic drusy some containing silver sulfide crystals, show up as black dots (right of center).

"W50-43A (Same locality as W50-43) Gold and silver ore, showing abundant dark patches and bands of sulfides." I.F.W.

This specimen differs somewhat from WJO-43, being a siliceous breccia, with much coarse grained syenitic (?) rock.

Polished section 668

This section, unlike any of the others, contains covellite, recognized by its characteristic pleochroism in blue and intense red birefringence colors. A greenish apparently isotropic mineral may be tetrahedrite.

"W50-44 Rayas Mine, level 255 S [illegible] altos 18S., part of Santa Margarita

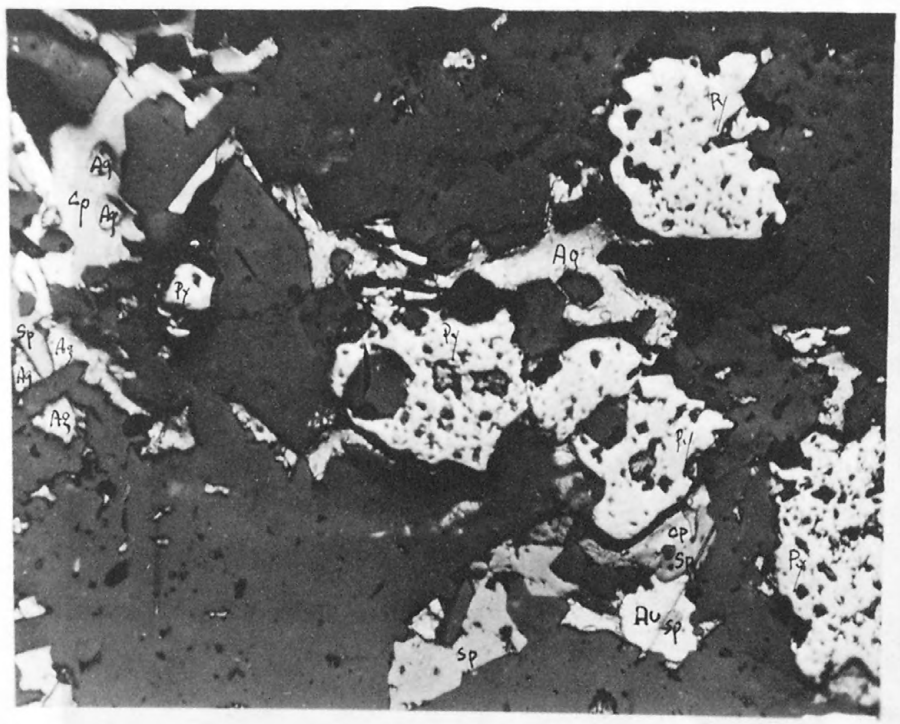
Gold and silver ore - very high grade, assay shows 30.9 g. Au and 15 kilos. Ag / ton." I.F.W.

Polished section 669

The specimen is a breccia heavily seamed with quartz veinlets, carrying abundant dark sulfide with pyrite. Although the mineralization is of the same general type as in the other specimens, there is more of it.

In polished section, the abundance of argentite is striking: gold is also present, but not apparently more so than in many other sections. The argentite is associated with pyrite which in some places it appears to replace; elsewhere it occurs in the usual association with galena, sphalerite and chalcopyrite.

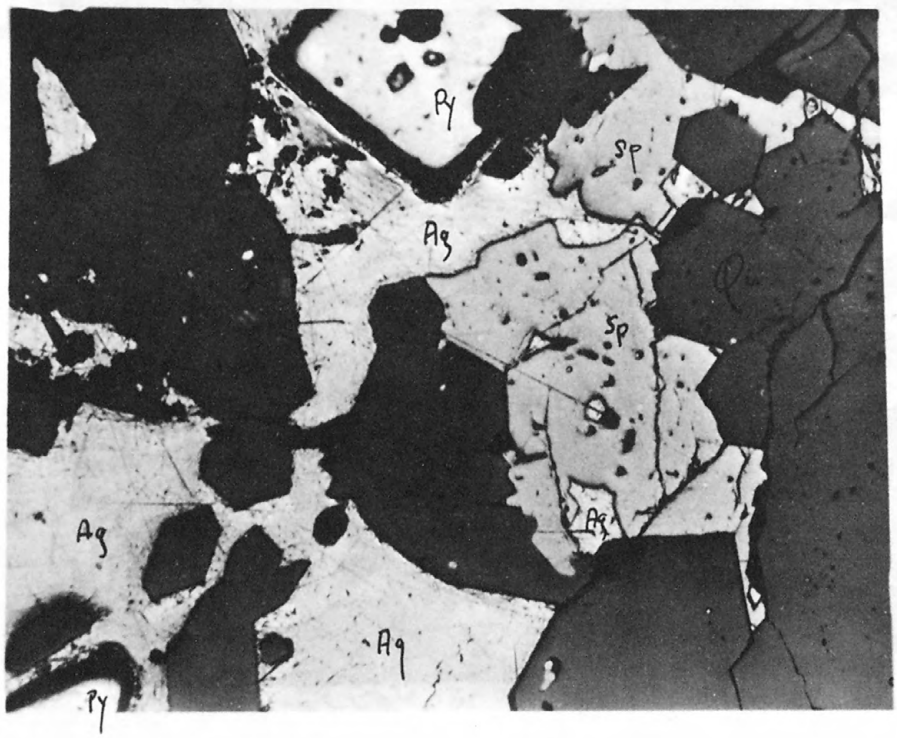
As usual, gold is scattered about in small grains, generally with argentite.



WJO-44 X150 Polished section 669

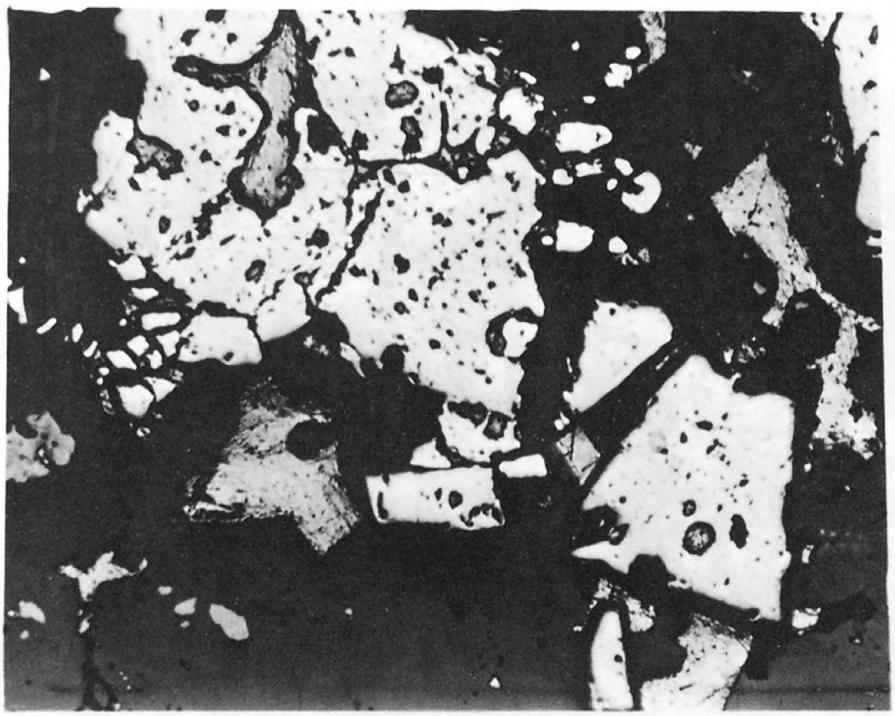
Pyrite (Py) Sphalerite (Sp) Argentite (Ag) Gold (Au)

Note sphalerite in gold (lower right) and argentite in chalcopyrite (upper left).



W50-44 X150 Polished section 669

Pyrite (Py) Sphalerite (Sp) and Argentite (Ag) in quartz. Note anhedral quartz and pyrite.



W50-44 X150 Polished section 669

Pyrite and argentite in quartz.

WJO-45 Rayas Mine level 275 N Pozo 70 N

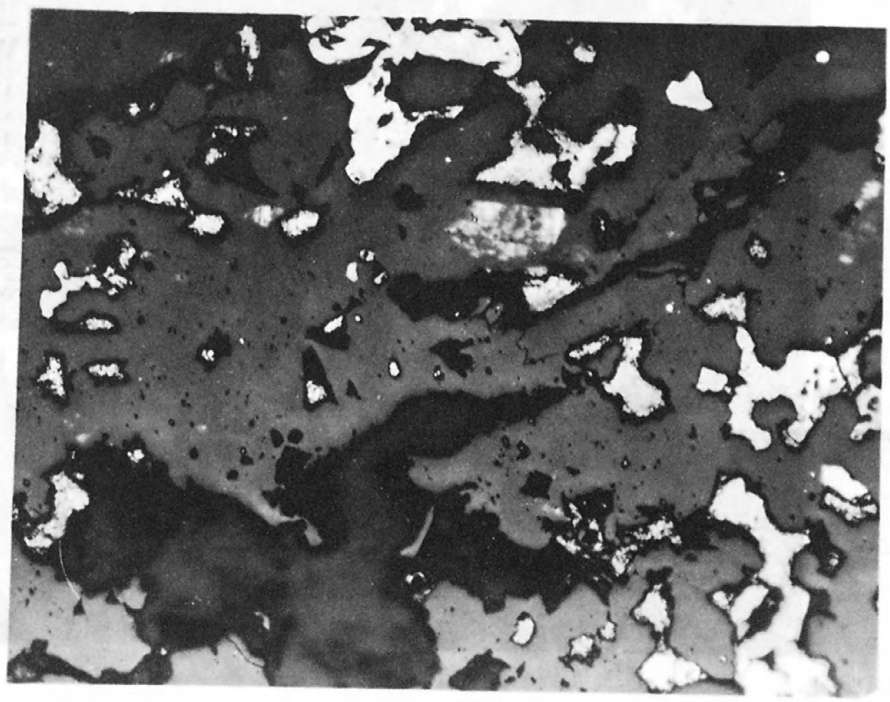
Santa Margarita vein N 35 W

"Gold and silver ore, showing dark bands rich in silver; also vuggy amethystine quartz." I.F. W.

The specimen is brecciated gray wall rock cut by quartz, amethystine in the vuggy center.

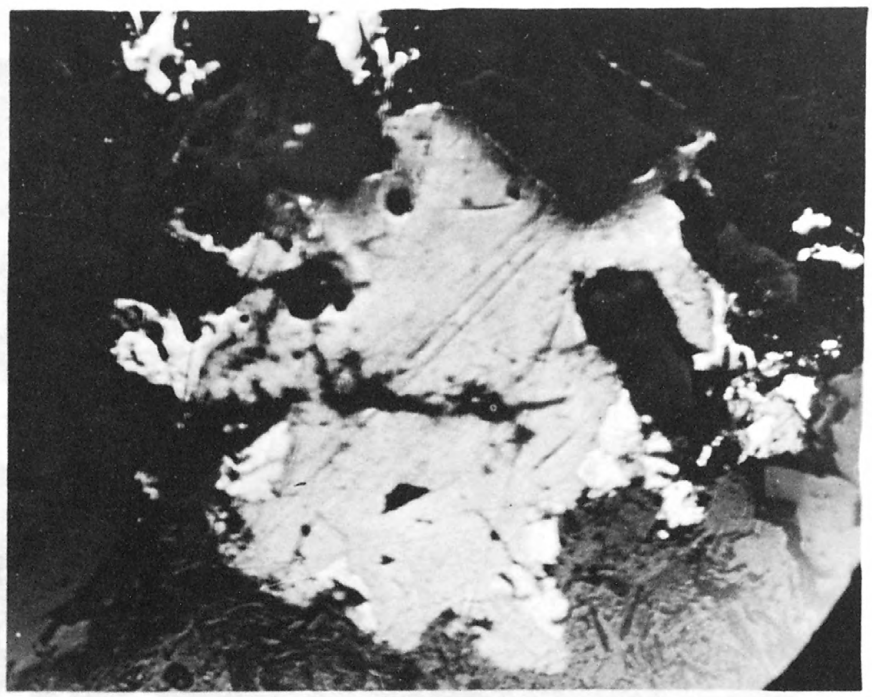
Polished section 605

The polished section shows the usual disseminated chalcopyrite, pyrite, galena, argentite and sphalerite. Sharply enhedral pyrite crystals in chalcopyrite show no porous structure. At the edge of the section; i.e. on a quartz druse is polybasite with a little galena, chalcopyrite and pyrite.



W50-45 X150 Polished section 605

Pyrite chalcopyrite



W50-45 X150 Polished section 605

Polybasite, bordered with galena and chalcopyrite

W50-45 X-150 Polished section 605

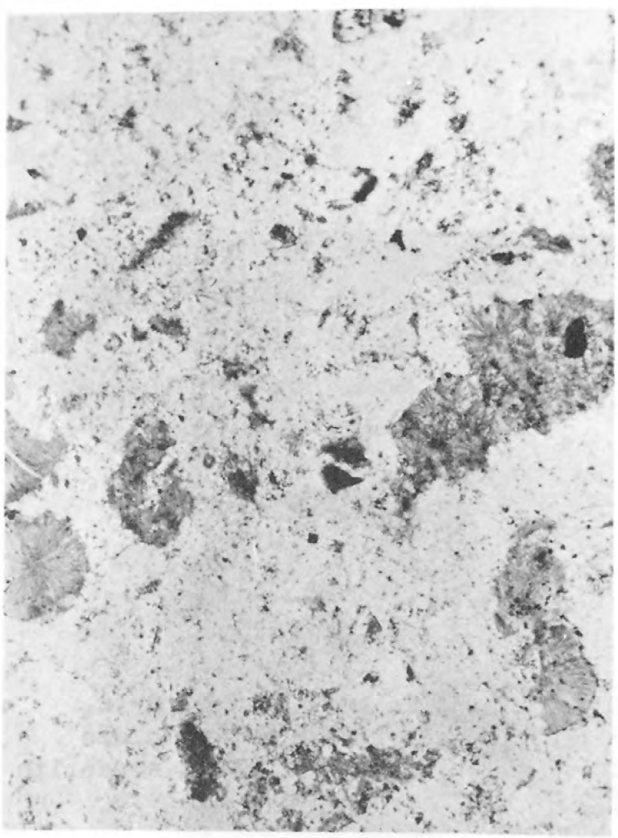
Enhedral pyrite, showing no porosity, in chalcopyrite.

"WSO-47 Tito Kurtz Mine above 55 level stope 358 N part of Veta Madre Gold and silver ore - soapy type called "jabon"." I.F.M.

Polished section 654

Greenish-grey soapstone. Very tiny sparsely disseminated pyrite grains.

Owing to the nature of the rock, perhaps, only pyrite was noted in the section; however, pyrite was the only metallic mineral noted in the hard specimen also.



Ordinary light

X nicols

W50-47

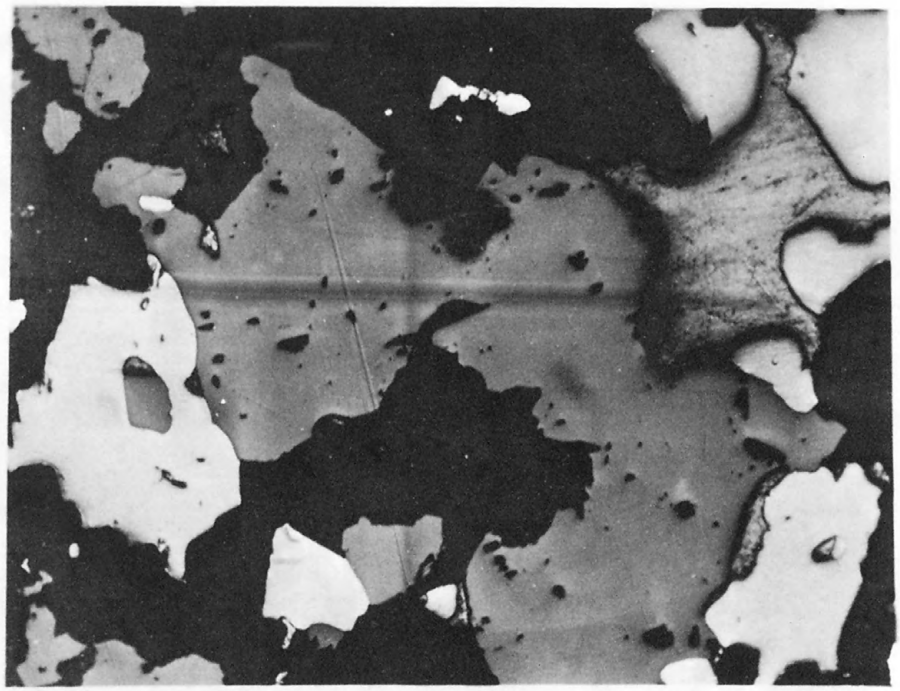
X47 thin section

Quartz and Saponite

"W50-52 Promontorio Mine level 50 N Crucero 248 S HW part of Veta Madre." I.F.W.

Polished section 612

This is a silicified limestone breccia in part, vein quartz cutting siliceous heterogeneous material. Chalcopyrite and pyrite are both visible to the eye; polished section galena, sphalerite and argentite are also seen.



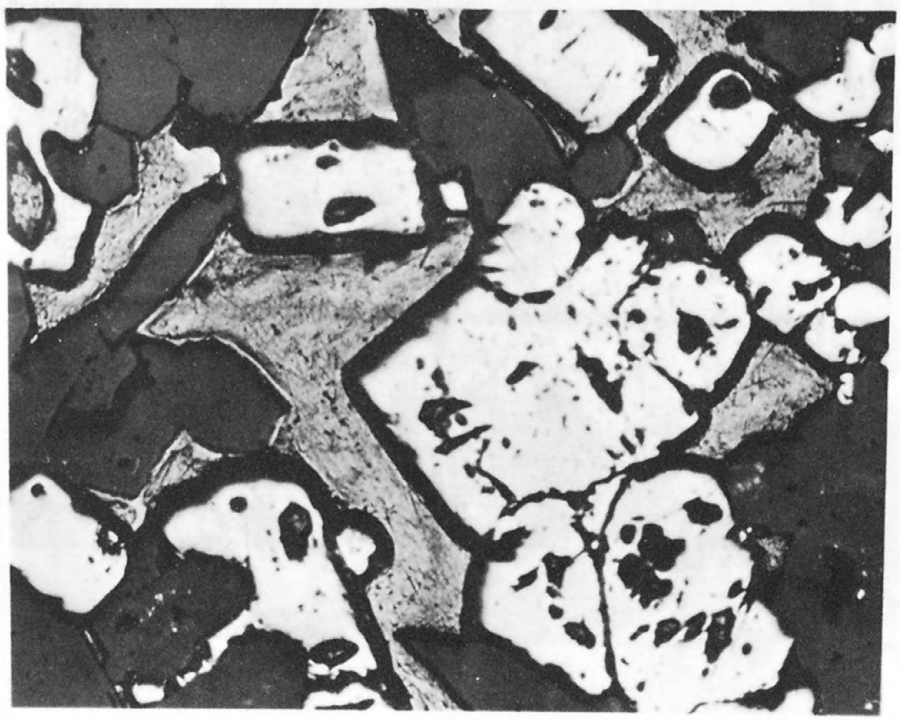
W50-52 X160 (Polished section 612)

Sphalerite, chalcopyrite and argentite.

"W50-53 Promontorio Mine, level 75 N Crucero alto 260S. Part of main vein, just below old stopes. Gold and silver ore, showing prominent dark bands of sulfides." I.F.W.

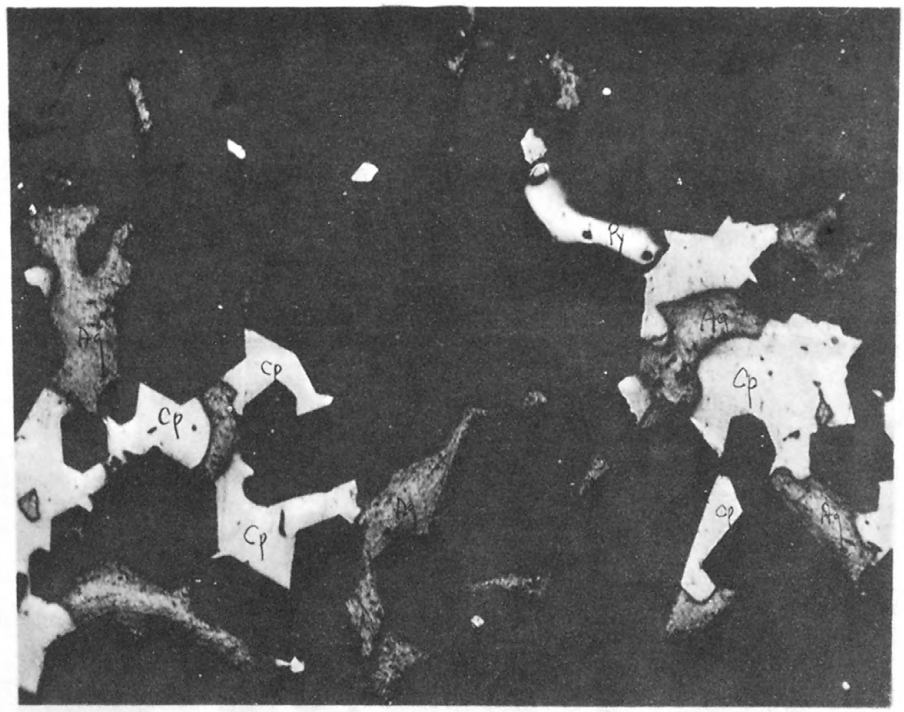
Polished sections 598 and 614

This is siliceous breccia with amethystene quarts, and irregularly distributed spotty mineralization.



W50-53 X160 (Polished section 614)

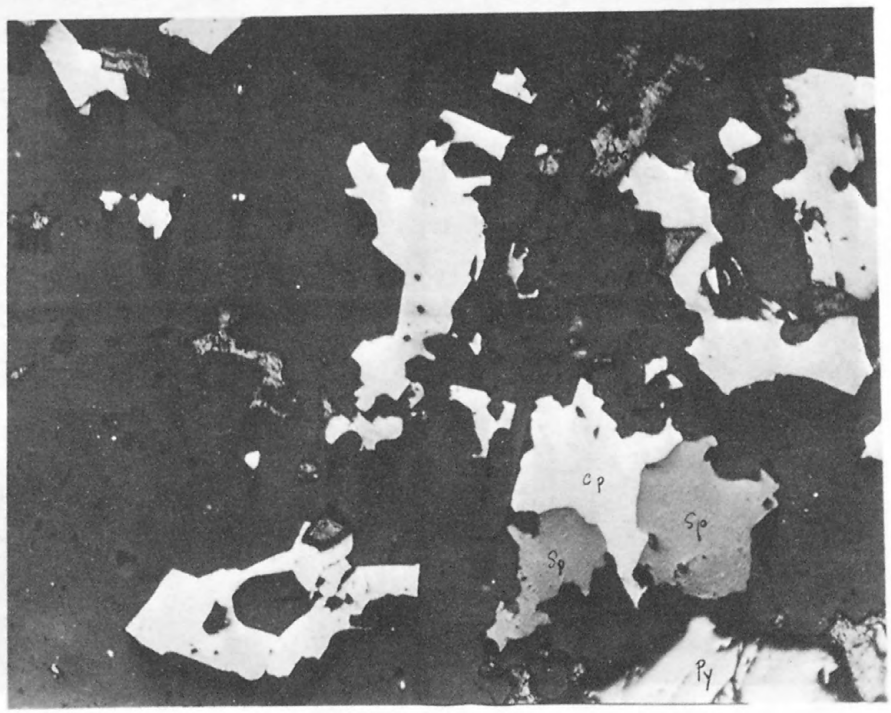
Pyrite and argentite



W50-53 X160 (Polished section 614)

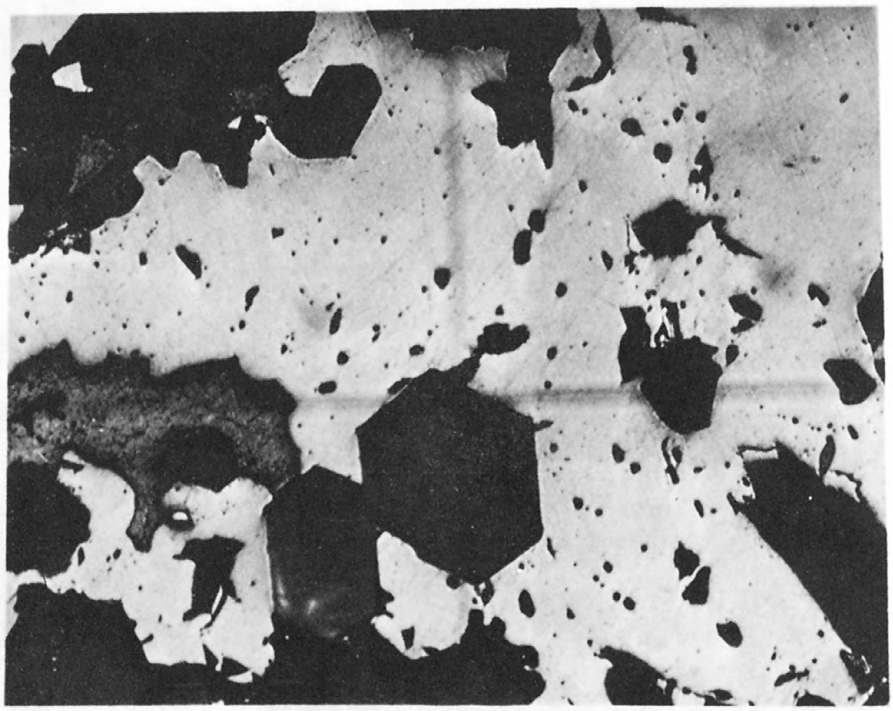
Chalcopyrite - argentite

Note enhedral quartz, around which the ore minerals have formed.



W50-53 X160 (Polished section 614)

Chalcopyrite (Cp) Sphalerite (Sp) argentite (Ag) Pyrite (Py)



WJO-53 X160 (Polished section 614)

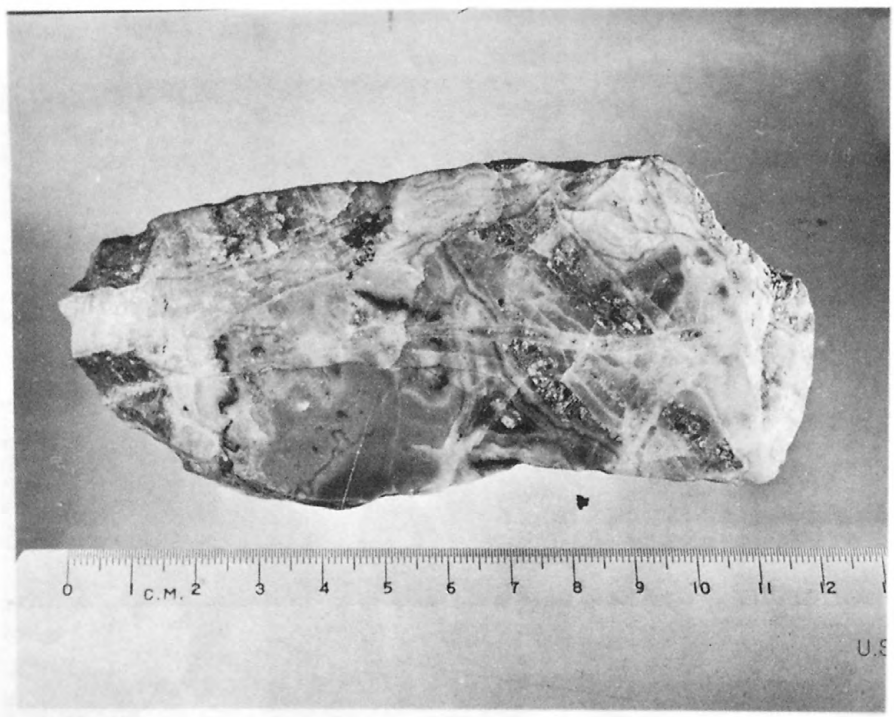
Chalcopyrite and argentite (left center). Note enhedral quartz.

"W50-54 Rayas Mine, 225 level Chiflon 11 gold and silver ore, showing native gold. Also interesting relations of quartz veinlets." I.F.W.

Polished section 698

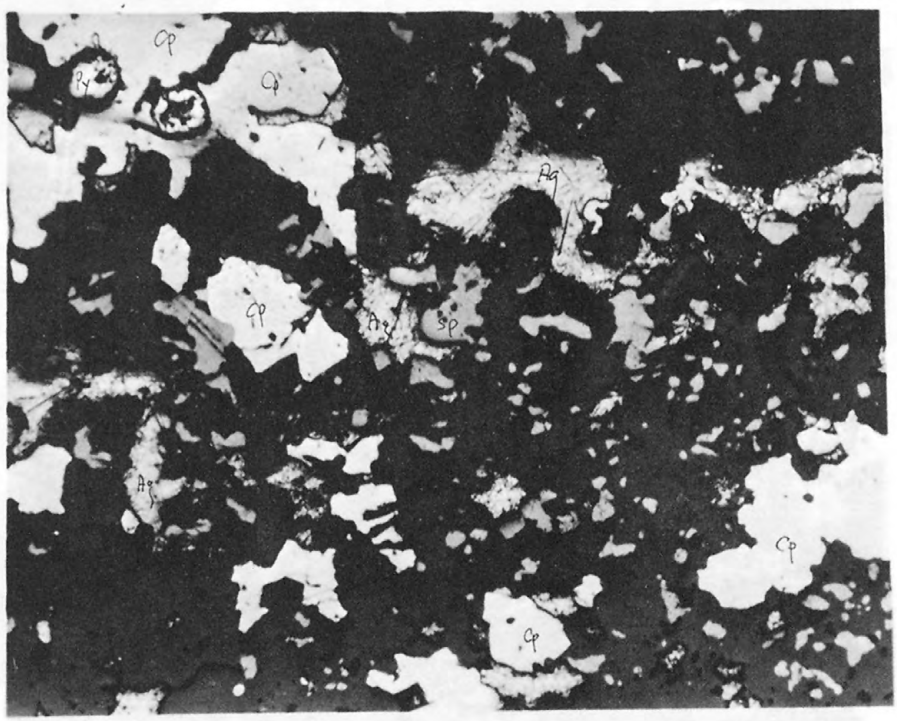
This specimen, illustrated below, is typical high grade ore. It also shows visible gold, usually microscopic.

The dark ore streaks in the hand specimen are seen to be as in all of the ore, not true banded veins but disseminations of ore-grains in quartz.



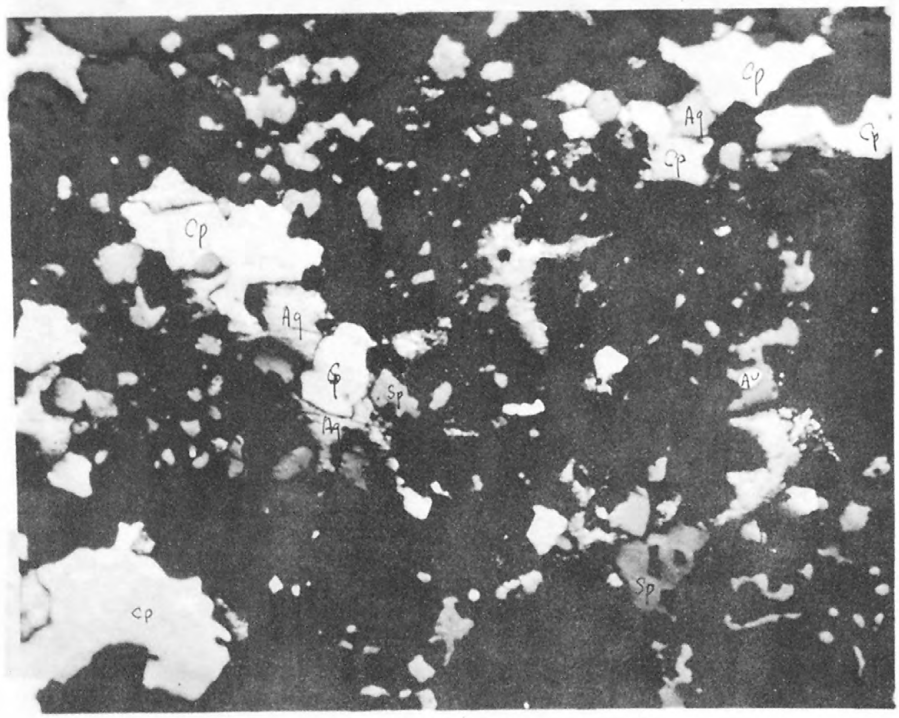
W50-54 Rayas Mine Sawed face.

Typical rich silver-gold ore, showing brecciated wall-rock fragments, and intricate quartz veining. The dark ore streaks are typically shown. Some of the quartz is amethystine, and there are small areas of (unreplaced?) rhombohedral carbonate.



W50-54 X150 Polished section 698

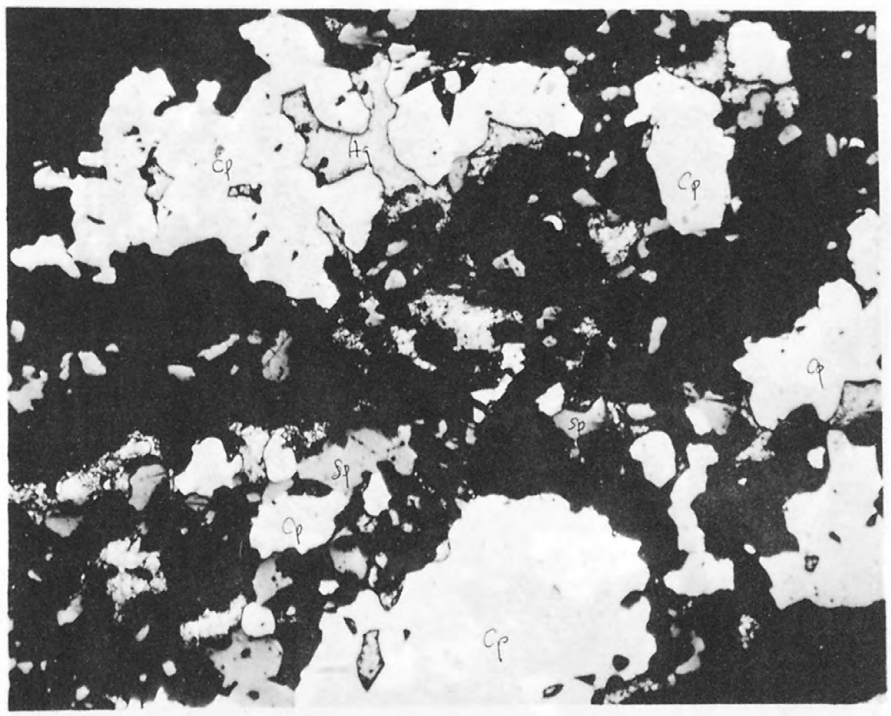
Shows disseminated chalcopyrite (Cp), Sphalerite (Sp) (the numerous small gray areas), with much argentite (Ag) with which is wire gold (Au).



W50-54 X150 Polished section 698

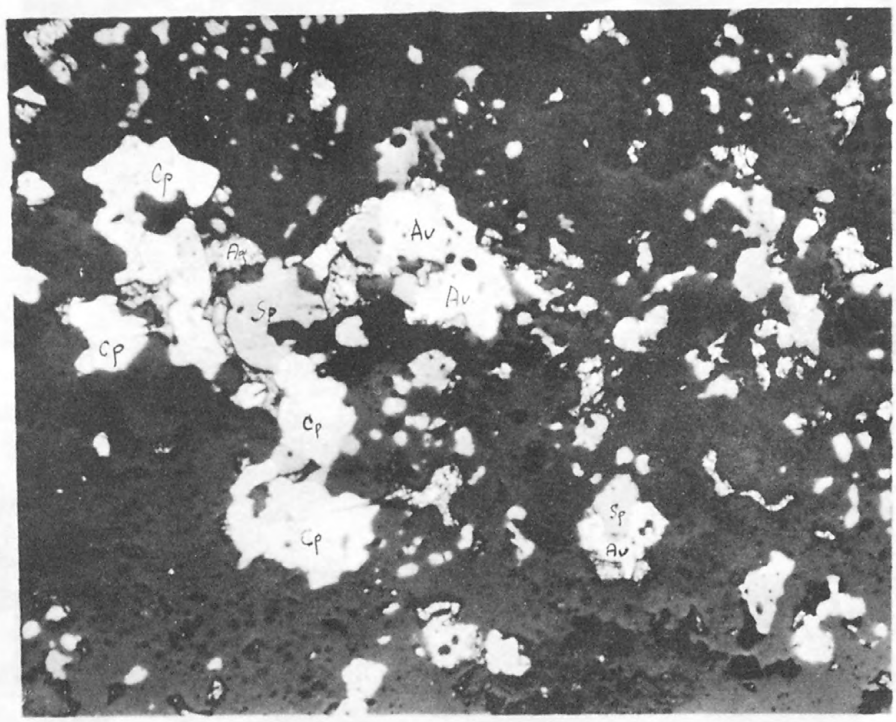
Chalcopyrite (Cp) Argentite (Ag) Gold (Au) Sphalerite (Sp).

Note rounded bleb of gold enclosed by Sphalerite (center right).



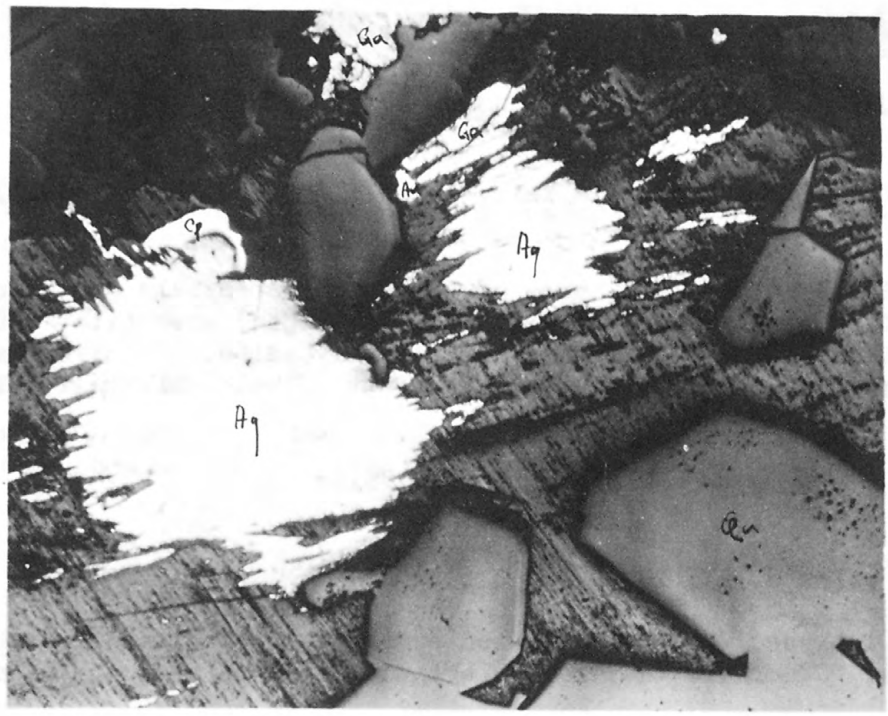
W50-54 X150 Polished section 698

Argentite (Ag) replacing chalcopyrite (Sp) Argentite with wire gold (Au) Sphalerite (Sp).



W50-54 X150 Polished section 698

Gold (Au) chalcopyrite (Cp) Sphalerite (Sp) Argentite (Ag)



W50-54 X150

Argentite (Ag) replacing carbonate (Ca) along cleavages of the latter. This carbonate which is in quartz-lined vugs is younger in than the quartz (Qu).

The argentite, unlike polybasite, is isotropic and shows no interval reflection. It has a greenish cast.

Calcopyrite (Cp), galena (Ga) and gold (Au) is also present.

Samples From the Los Pozos Vein (part of Veta Madre) 36, 37, 40

W50-36 Some unusual features (a) a later pyrite-marcasite vein deposition, free from the other base or noble ore minerals (b) the presence of argyrodite, silver germanium sulfide (c) wire silver with galena. Presumably there has been further mineralization, not noted in the other localities.

W50-37 Also contains marcasite-pyrite.

W50-40 Resembles the usual Veta Madre ore; it shows an unusual alteration of pyrite in chalcopyrite.

Samples from Santa Margarita Vein, paralleling Veta Madre, 5, 11, 44, 45

At least the last three of these four specimens are noted as being of better than usual grade, W50-11 has (macrosopic) argentite, W50-44 probably likewise, and W50-45 has visible polybasite. This vein may have been enriched by a late argentite sulfo salt - (gold) mineralization.

Samples from E-W Veins

San Martin veins 6, 13, 19

Of these, W-50-19 contained coarsely crystallized argentite and pyrargyrite. Otherwise they resemble the usual type of Guanajuato ore.

San Cipriano veins 8, 39

Both of these are pyritized wall rock, with abundant argentite and polybasite in W50-39.

Santa Cecilia veins 18, 32

No unusual characters. W50-32 is silicified wall rock.

Sample from N 25 W veins, 3

Vuggy quartz with polybasite.

Sample from footwall vein in shales 29

Mostly chalcopyrite, with included pyrite.

Comparison of the Several Samples From Each Vein System

Before attempting to ascribe specific differences to the mineralogy of the several vein systems, it should be noted that a general similarity holds for practically all of the specimens studied. Such differences as may be found are minor, and may or may not reflect significant changes in time or conditions of mineralization. Argentite (a canthite) and gold (electrum) are consistently the carriers of the silver - gold of the ore; invariably they are accompanied by galena, chalcopyrite, sphalerite, and pyrite. Polybasite and argyrodite accompany the argentite in but a few of the specimens studied; it is certainly possible that there were more specimens from each occurrence studied these minerals, and perhaps others, might be found more often than they were. There, however, seems to be reason for believing that the complex sulfo-salts, such as polybasite, the ruby-silvers, etc. represent a late crystallization, for the most part in coarse crystals in vugs and open cavities; that the present-day ore is not especially rich in these minerals.

With these preparatory remarks, the various vein systems will be considered as represented by the samples at hand.

Samples from Veta Madre:

1, 15, 20, 24, 27, 28, 41, 42, 43, 43A, 47, 52, 53.

Of these, W50-24, "charasco" ore, is evidently different from the others, however, unusual local conditions of leaching, oxidation, etc. may account for this.

W50-27 and W50-28 (also W50-29) contain shale fragments with more or less carbon (graphite).

W50-47 ("jabon" ore) greenish grey soapstone, is different from the others.

With these exceptions, all of the Veta Madre specimens examined appear to be igneous and sedimentary breccias,, with calcification and replacement of the calcite-cemented breccia by quartz veins, which are often amethystine. The ore mineralization, base and noble, appears to have occurred with the silicification; at a late stage of the process, hydrothermal solutions deposited relatively large crystals of argentite and complex silver salts in the quartz-lined vugs.

Another characteristic of the mineralization is its spottiness; there are no banded ore veins, but the ore minerals occur in scattered irregular areas rarely over a centimeter across, usually much less, or in thin discontinuous veinlets, a millimeter or so wide. And usually the mineralization is at the edge of the quartz veins, against the fractured rock particles.

Observations on Paragenesis

It is generally agreed, and the present study concurs that of the metallic minerals, the oldest is pyrite. Whether or not pyritization and calcite deposition occurred simultaneously during brecciation is not evident: a study of wall rock alteration might clarify this. The replacement in whole or part of calcite by quartz followed; with and after the formation of quartz, the lead-zinc-copper-silver-gold mineralization occurred. After the main mineralization, there is evidence for deposition of germanium as argyrodite, and antimony as complex silver sulf-antimonides.

From the microscopic relations of the chalcopyrite and sphalerite and galena they appear to be essentially contemporaneous. Replacement of one mineral by another is shown, but this is in general reciprocal with no clear indication that one has consistently been replaced by another. Galena, however, is in many sections seen to be replaced by argentite.

The comparative absence of complex silver sulfo-salts in the ores now mined as represented in these samples: in particular, of tetrahedrite. and ruby silvers, with their scanty occurrence as crystalline masses of rather large dimensions in vugs, suggests that the Guanajuato ores as a whole represent a rather shallow deposit, whose upper richer levels have been worked out. The bonanza ores of the past, now seldom if ever encountered, appear to have been great masses of coarsely crystallized silver minerals. The presence of cinnabar reported from Guanajuato, confirmed by a small production of mercury, likewise suggests the upper part of an ore deposit. Antimony (arsenic), mercury, and perhaps selenium and germanium, may represent the more fugitive components of the ore magma, less likely to be fixed at an early stage of the mineralization, more likely to concentrate in the later relatively cool upward-moving hydrothermal solutions. Silver (gold) compounds of these elements would, therefore, tend to form in the later-higher parts of the mineralized region. If these views are correct, mining in depth is less likely to uncover spectacular masses of complex sulfo-salts, but may encounter economic concentrations of base metal sulfides with continuing enrichment in argentite-gold.

Temperature of Vein Formation

A study was made by Houston of the temperature of formation of the quartz crystals from Guanajuato.

The method was to note the temperature at which the gas-liquid contents of vacuoles in the quartz. The assumption underlying the method is that fluid completely filled the vacuole at time of its formation; i.e. when the quartz crystal grew enclosing the fluid; that on cooling, the fluid shrank, occupying less volume, with a gas phase in equilibrium with the liquid - reversal of the process - by slow heating of the rock - will cause the last of the gas phase to disappear at the precise instant and temperature at which a single fluid phase fills the vacuole.

Thirty such measurements on quartz crystals from the Rayas Mine (W50-56) gave a range from 215°C. to 299°C. - average 254°C. (which is also close to the mean of the highest and lowest values, 257°C.). Correction for pressure due to depth of cover will not alter these figures greatly - 20°C. or 30°C. will be the correction to be added for in depth of a mile.

Lindgren, Bateman, and other authorities have classed Guanajuato as epithermal or the basis of texture, mineralogy, shallow bottoming, etc. But the formation temperature obtained from the vacuoles in these quartz crystals, especially after the pressure correction is added, is well into Lindgren's mesothermal zone. In this connection, it is interesting to note that Wandke and Martiney __/ state "the temperature of the solutions was undoubtedly that of Lindgrens low and middle zones".

In summary, it appears that the Guanajuato mineralization is hydrothermal, that is, deposition from moderately hot aqueous solutions, below the critical point of water. Wandke and Martiney suggest gaseous solutions, on the assumption, however that the temperature exceeded the critical temperature of water at a pressure of several thousand meters of rock.

Recovery of Copper, Zinc, and Lead

Examination of the many specimens of gold-silver ore from the Guanajuato district leads one to weigh carefully the statements of Wandke and Martinez (page 17), "The base metals such as lead, zinc, and copper are present only in traces except for local [illegible] or shoots," and "The ores consist of silver sulfides and silver [illegible] in which occur, in minor and almost insignificant amounts, such base minerals as galena, sphalerite, and chalcopyrite".

At a minimum estimate, there is at least ten times - fifty times might be closer to the truth - of base metals as there is silver in these samples. Indeed, two small producers in 1944, according to Guiza, Rendon, and Baltierra (page 72, Table 8), produced ore running over 1% in copper — only 38 tons of ore, yielding 253 kg. of copper, associated with extraordinarily rich silver-gold ore. When it is considered that several hundred thousand tons of ore mined annually, producing some 35,000 kg. of silver (1944-5), that a conservative estimate, 350,000 kg. of base metals are mined but not milled. Valuing these at a round figure of 50¢ a kg. would give around $200,000.00 worth of base metals run off in slags and tailings. The 1944-5 production of precious metal was roughly 1100 kg of gold valued at $1,000,000.00 and 34,000 kg. of silver valued at 1,100,000.00

$2,100,000.00

Evidently then the total of base metal would only be a fraction of the value of the noble metals if an economic process of recovery could be devised. At an optimistic estimate, possibly half as much.

With increasing value and demand for base metals, and taking into account the vast tailing piles which presumably might be re-worked, and that there is an existing mining plant equipped with machinery, working equipment and staff, etc. thought might be given to recovery of the accumulated base metal as a side-line to main operations. It might also be feasible eventually to re-work similar discards from other mining districts, perhaps shipping them to a convenient central point where milling facilities exist.

An examination, with adequate assays and mineralogical study, of the dumps should be made, followed by a study of metallurgical methods of separating the intimately interlocked zinc, copper, lead, and iron.

Recovery of Germanium and Mercury

This present study has shown that germanium, in the form of argyrodite, silver germanium sulfide, is present in the ore. There has also been a small recovery of mercury, as cinnabar or possibly mercurian tetrahedrite.

It might be feasible, in view of the present importance of germanium, to attempt its recovery. Doubtless the germanium occurs in restricted parts of the Guanajuato workings. It might be possible to detect this metal spectrographically. However, the visual spectrographic technique described by Peterson, Kauffman, and Jaffe (Am. Min. 32, 322-335, 1947) is not sensitive enough*, requiring about 0.5% Ge for visible spectral lines, and thus being adequate for identifying germanium minerals as such, rather than revealing its presence in ore samples. At present, therefore, the cost of determining the presence of germanium is a bar to its extraction from the Guanajuato ore. If a cheap method for detecting germanium in concentrations on the order of .01% could be developed, then attention could be directed to its recovery from the ore if such quantities could be shown to be present.

* Personal communication from K. J. Murata of the Geological Survey, Spectrographic Laboratory.