U.S. GEOLOGICAL SURVEY

DEPARTMENT OF THE INTERIOR

Shawangunk Ore District, New York: Geochemical and Spectral Data

by

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This report is preliminary and has not been reviewed or edited for conformity with USGS standards and nomenclature.

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Abstract

This report presents ICP geochemical analyses, ultraviolet-infrared spectral reflectance and fluorescence excitation-emission-matrix (EEM) data, sulfide and lead isotope systematics, and paragenetic information on the epigenetic Shawangunk ore district of southern New York (Ulster, Orange and Sullivan Counties).

Ultraviolet-near infrared (UV-NIR) spectral reflectance curves and fluorescence EEM data for sulfide minerals are the first reported in the literature for the Shawangunk deposits. In the UV-NIR reflectance curves of sphalerite, the 2.5 μm feature is interpreted as probably due to a Fe2+ tetrahedral sulfide crystal field band. The 1.0μm band in the spectra of the pyrite specimens from the Taconian unconformity surface looks more like geothite than pyrite, suggesting that these samples were coated with iron oxides. Alternatively, the 1.0 μ band may be due to a FeS_2 crystal field transition of pyrite.

The quenching effect of iron on fluorescence in sphalerite in the visible and near-visible bands is graphically represented by excitation-emission-matrix (EEM) data for the Shawangunk district samples in contrast to a low-iron sample from Summit County, Colorado.

Major and minor element analyses in relation to sulfide and lead isotope data suggest a relatively homogeneous ore district with slight internal trends. Sulfur $\delta^{34}S$ for sphalerite increases slightly from +25.7 per mil to +28.0 per mil to the southwest within the district, parallel to a slight decrease in radiogenic lead of galena and a decrease in iron content of sphalerite (from 8.2% at Ellenville to 3.7% at Guymard).

In relation to sulfide deposits of the North American craton, generally identified as Mississippi-Valley-Type (MVT) deposits, Shawangunk sphalerites have high $\delta^{34}S$ values and galenas are low in radiogenic lead.

It is perhaps of genetic significance that the Shawangunk deposits are similar in lead isotope ratios and trace-element geochemistry, e.g., in Cd:Mn ratios in sphalerite, to deposits which occur at the Triassic-Jurassic border faults of the Newark Series basins, and to deposits elsewhere along the Alleghanian-Variscan and Post-Variscan tectonic belts of eastern North America and northern Europe. Shawangunk district sphalerites, however, have relatively high Ti and Fe contents.

I. Introduction

This open-file report contains analytical geochemical and geophysical remote sensing data (including ultraviolet-infrared spectral reflectance data and fluorescence excitation emission matrix (EEM) data on sulfide minerals) for the Shawangunk region of Ulster, Orange, and Sullivan Counties, New York, with emphasis on the Shawangunk base-metal sulfide deposits and on new data bearing on their genesis. This report, used in conjunction with additional geochemical data emphasizing sulfur and lead isotope systematics, fluid-inclusion salinity and temperature data, and additional geochemical analyses (Wilbur and others, in press) provides a data base to compare the Shawangunk group of deposits with other base-metal sulfide deposits for purposes of classification, relationship to metallogenic province and genesis. Most field sample numbers are identical to those of Wilbur and others (in press), and represent splits of the same samples, separately analyzed by the Geological Survey; data from additional ore samples are reported in the sections on polished-section photomicrography, parageneses and sulfide-isotope systematics. In the section on sulfide isotope systematics, we have collated all known $\delta^{34}S$ data for the Shawangunk ore district since 1957.

The current investigations, represented in part by the data sets of this report, were designed to treat the Shawangunk deposits in a regional sense as a genetic group, carrying previous work on individual mines to the next logical step, in which trace element geochemistry, isotope systematics and UV-NIR spectral data are analyzed in relation to regional remote sensing and geophysical and geological map data. Specifically, the Shawangunk ore deposit occurrences were studied in relation to airborne synthetic aperture radar mosaics, optically corrected and fit to the Scranton 2°Q, 1:250,000-scale topographic base and to Landsat Multispectral Scanner frames, for fracture pattern analysis. The ore occurrences and regional geology were also studied in relation to aeromagnetic and gravity potential-field map data and in relation to airborne aeroradioactivity surveys using a gamma-ray method and data from the National Uranium Evaluation Program.

II. Ore minerals and parageneses

Table 1. Significant occurrences of sulfide-bearing veins, Shawangunk Mountains, New York[*]

Locality Latitude N; longitude W; elevation (Location point)	Host rock[1]/ Vein structure Other ore controls	Workings Dates of activity[2]/ Production,[3]/ reserves	References
Delaware Aqueduct, Wawarsing 41°45'17"; 74°20'39";-122m (Rondout Tunnel Sta. 291+28)	Upper Ss. Reverse fault N35°E; 45°W.	Tunnel cut 15m wide Mineralized zone. No development. 1941(D).	Bird (1944); Freund (1941-42); Moxham (1972)
Railroad quarry, Napanoch 41°43'47"; 74°22'08"; 100m (Quarry)	Upper Ss. N36°E; 38-44°W. Faults N24°W; 70°E. Minor disseminated mineralization along bedding.	Quarry, prospect pits. 1840s-1863(E). Other prospects in vicinity. No production.	Friedman (1957); Heusser (1976a,b, 1977)
Sun Ray(Old) Mine, Ellenville 41°42'57"; 74°22'48"; 110m (Adit portal)	Upper Ss. N35°E; 38°W. Fault N30°W; 70°E. Minor disseminated mineralization along bedding.	150m adit; decline; prospects Before 1728(D); 1730s, 1777-78, 1820s, 1850s 1906(E). Minor production(?).	Beck (1842); Flescher (1979); Heusser (1976c, 1977)
Ulster Mine, Ellenville 41°42'42"; 74°23'00"; 113m (Adit portal)	Upper Ss. N30°E; 46°W. Fault N30°W; 77°E flattens to 40°E at 30-35m. Ore shoots plunge NW. Minor disseminated mineralization in wall rocks.	Adit; 60m shaft, 5 levels; prospect pits. 1849(D); 1852-54, 1862-63, 1870s or 1880s(P); 1903-04, 1917(E). Production: ~725 tonnes Pb, 45 tonnes Cu, some Zn.	Flescher (1979); Friedman (1957); Gray (1953); Heusser (1976c, 1977); Ihlseng (1903); Ingham (1940); Nason (1894)
Buttermilk Falls, Spring Glen 41"40'08"; 74°24'56"; 131m (Adit portal)	Upper Ss. N35°E; 48°W. Fracture N45°W. Minor disseminated mineralization.	75m adit. 1852(E). No production.	Friedman (1957); Gray (1953)
Red Bridge Mine, Spring Glen 41°39'54"; 74°24'38"; 305m (Lower adit portal)	Upper(?) Ss. N30°E; 45°W. Reverse fault N28°E; 78°W.	3 adits; prospect pits; trenches. 1836-1840(E) No production.	Beck (1842); Gray (1953); Mather (1843)
Shawangunk Mine, Summitville 41°35'38"; 74°26'41"; 332m (Upper workings adit portal) 41°35'42"; 74°27'03"; 171m (Lower adit portal)	Upper Ss. N35°E; 35°W. Reverse fault N35°E; 30-50°W Ore in shoots where dip flattens and/or strike changes.	3 shafts; 2 adits; 335m of stopes and drifts. 1813(D); 1830s-1860s, 1917-1920(P); 1948-1949, 1961, 1979(E). Production: ~800 tonnes Zn, 350 tonnes Pb, 10 tonnes Cu. Reserves: >100,000 tonnes @ ~6% Zn, 0.5% Pb.	Beck (1842); Crawford (1981); Crawford and Beales (1983); Ellertsen (1950); Friedman (1957); Gray (1953, 1961); Heusser (1977); Mather (1843); Sims and Hotz (1951)
Washington Mine, Otisville 41°28'15"; 74°33'41"; 323m (Upper workings)	Upper Ss. N35°E; 33-40°W. Reverse faults N10-15°E; 55-77°W.	3 adits; 2 shafts; prospects. 1863-64, 1906-07(E). No production.	Gray (1953); Hartnagel (1927)
Wallkill Mine, Guymard 41°26'26"; 74°34'48"; 365m (Location approximate)	Upper Ss. N25°E; 30°W. Faults N30°W.	Prospects. 1863-1864(E). Minor production(?).	Crawford (1981)
Guymard (Erie) Mine, Guymard 41°25'48"; 74°35'30"; 256m (No. 1 shaft collar)	Upper Ss. N20-30°E; 35-40°W. Fault N90°E; 90°. Ore shoots plunge 60°W. Some disseminated mineralization in wall rocks.	2 shafts; 2 adits; stopes, drifts; prospects. 1862(D); 1863-1876, 1880s(P); 1917, 1948-50(E). Production: ~1,090 tonnes Zn, 900 tonnes Pb.	Gray (1953); Grugan (1918); Hartnagel (1927); Neumann (1952)

1/Host rock: Ss - Shawangunk Formation. Strike and dip of host rock and structure, where indicated.
2/Dates of activity: (D) — date of discovery; (P) — dates of production; (E) — dates of exploration.
3/Production: Metal tonnages given are estimates for amount of ore removed. Actual shipments, or metal recovered, may have been smaller.
*/From Wilbur, S., Mutschler, F. E., Friedman, J. D., and Zartman, R. (written comm., 1988).

Table 1a. Ore samples by field sample number, major Mineral, $\delta^{34}S$, and location, Shawangunk Region, New York

Sample	Mineral	$\delta^{34}S$	Locality
S 26-8	FeS2	+35.1	Ellenville (Ulster) Mine, Ellenville, Ulster County, NY
S 26-34	ZnS	+24.6	Ellenville (Ulster) Mine, Ellenville, Ulster County, NY
S 26-35	ZnS	+25.4	Ellenville (Ulster) Mine, Ellenville, Ulster County, NY
S 26-36	$FeCuS_2$	+23.9	Ellenville (Ulster) Mine, Ellenville, Ulster County, NY
S 26 37	$FeCuS_2$	+23.7	Ellenville (Ulster) Mine, Ellenville, Ulster County, NY
S 26-39	PbS	+22.9	Ellenville (Ulster) Mine, Ellenville, Ulster County, NY
S 26-40	PbS	+21.2	Ellenville (Ulster) Mine, Ellenville, Ulster County, NY
S 29-4	FeS_2	+19.8	High Falls, Ulster County, NY (High Falls Shale)
S 29-5	FeS_2	+20.8	High Falls, Ulster County, NY (High Falls Shale)
S 30	FeS_2	+34.8	Railroad quarry, Napanoch, Ulster County, NY
S 54-1	PbS	+23.1	Shawangunk Mine, Summitville, Sullivan County, NY
S 54-4*	PbS	+22.0	Shawangunk Mine, Summitville, Sullivan County, NY
S 54-4*	ZnS	+25.7	Shawangunk Mine, Summitville, Sullivan County, NY
S 54-5	ZnS	+26.0	Shawangunk Mine, Summitville, Sullivan County, NY
S 102-4	PbS	+25.6	Guymard Mine, Guymard, Orange County, NY
S 102-7	ZnS	+27.2	Guymard Mine, Guymard, Orange County, NY
S 102-8	ZnS	+27.6	Guymard Mine, Guymard, Orange County, NY
S 102-17	PbS	+25.0	Guymard Mine, Guymard, Orange County, NY
S 105-1	PbS	+25.3	Washington Mine, Otisville, Orange County, NY
S 105-2	PbS	+25.0	Washington Mine, Otisville, Orange County, NY
S 105-14	ZnS	+27.4	Washington Mine, Otisville, Orange County, NY
S 105-15	ZnS	+28.6	Washington Mine, Otisville, Orange County, NY
S 140-1	FeS_2	- 2.3	Basal Shawangunk Fm., US Highway 84, Port Jervis S. quad., NY
S 142-1	FeS_2	- 2.8	Basal Shawangunk Fm., US Highway 17, Wurtsboro quad., NY
S 200-1	PbS	+12.4	Callanhan's quarry, Connelly, Ulster County, NY

25 samples

Analyses by Geochron Laboratories, 1985

*Contains both ZnS and PbS

Table 1b. Location data for Shawangunk galena samples
Analyzed[1] for lead isotope ratios

Ulster Mine, Ellenville, Ulster County, NY
N41°42'42"; W74°23'00"; Ellenville, N.Y. 71/2' quad (1969)
S26-39 Coarsely xln galena
S26-40 3 cm galena xl showing (001, 111)

Shawangunk Mine, Wurtsboro, Sullivan County, NY
N41°35'42"; W74°27'03"; Wurtsboro, N.Y. 71/2' quad (1969)
S54-1 Fine xln galena
S54-3 Coarsely xln galena

Guymard Mine, Guymard, Orange County, NY
N41°25'48"; W74°35'30"; Otisville, NY 71/2' quad (1969
S102-1 Sheared fine xln galena
S102-8 Coarsely xln galena

Washington Mine, Otisville, Orange County, NY
N41°28'15"; W74°33'41"; Otisville, NY 71/2' quad (1969)
S105-2 Coarsely xln galena

Callanhan's Limestone Quarry, Connelly, Ulster County, NY
N41°54'27"; W73°59'53"; Kingston East, N.Y. 71/2' quad (1969)
S200-1 Coarsely xln sphalerite with some galena replacing New Scotland(?) Limestone

[1]/Analyses by Robert Zartman, USGS

Table 1c. 19th and Early 20th Century Specimens of Shawangunk Ores. From the G.J. Brush Collection and the Peabody Museum Collection, Yale University

B-1727	Chalcopyrite with quartz, Ellenville, Ulster Co., New York 3.25 x 3.5 x 3.5 cm.
B-883	Sphalerite, with iron oxide, Ellenville, New York 2.5 x 2.5 x 4 cm.
B-3174	Sphalerite, with quartz (brookite not on this specimen), Ellenville, Ulster Co., New York 2 x 3.5 x 7 cm.
B-3171	Brookite, Ellenville, New York 3 x 1 fragments in glass vial
B-3539	Quartz, with chalcopyrite, Ellenville, Ulster Co., New York 2 pieces: 3 x 4 x 4 cm., 2 x 2 x 2.5 cm.
B-3597	Quartz, Ellenville, New York one crystal 1.25 x 2 x 3.5 cm.
B-3632	Quartz, Otisville, Orange Co., New York 2 x 1s: 0.7 x 0.8 x 2.4 cm., 0.5 x 0.6 x 1.9 cm.
PM-8902	Quartz, Ellenville, New York one crystal x 1 1.25 x 4 x 4.5 cm.

Specimens from the G.J. Brush Collection are designated B-####, and specimens from the Peabody Museum Collection are designated PM-####.

Table 2. Primary Minerals of the Shawangunk District Compared to Similar Lead-Zinc Producing Districts[1]

Minerals Classified	Shawangunk	Tri-State	Central Missouri	Southeastern Missouri	Northern Arkansas	Illinois-Iowa-Wisconsin		Central Kentucky	Illinois-Kentucky Fluorspar District
Native Metals									
Silver (native ?)	X	X							
Gold	X								
Sulfides									
Pyrite	X	X	X	X	X	X	X	X	
Marcasite		X		X	X	X	X	X	
Chalcopyrite	X	X	X	X	X	X	X	X	
Millerite		X							
Siegenite				X					
Galena	X	X	X	X	X	X	X	X	
Sphalerite	X	X	X	X	X	X	X	X	
Wurtzite (primary ?)		X				X			
Sulfo-salts									
Enargite		X			X				
Halides									
Fluorite							X	X	
Oxides									
Quartz	X	X	X	X	X		X	X	
Chert		X			X				
Rutile	X[2]								
Brookite	X								
Carbonates									
Calcite		X	X	X	X	X	X	X	
Dolomite		X		X	X				
Aragonite		X							
Witherite							X		
Silicates									
Dickite				X					
Adularia					X				
Sulfates									
Barite		?	X			X	X	?	
Celestite							X		
Strontianite							X		

[1]Data on Missippi Valley districts taken from Bastin et al (1939, p. 106).
[2]Nason, 1894, p. 591.

Table 3. Secondary Minerals of the Shawangunk District Compared to Similar Lead-Zinc Producing Districts[1]

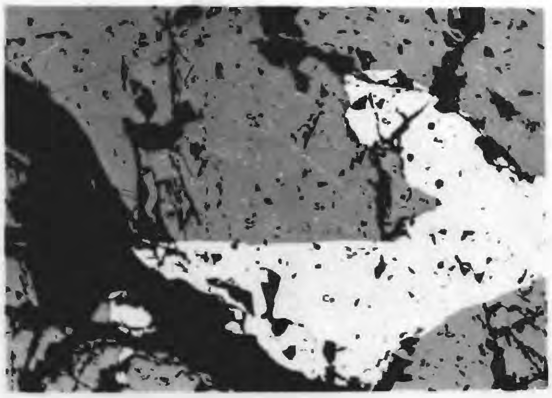
Minerals Classified	Shawangunk	Tri-State	Central Missouri	Southeastern Missouri	Northern Arkansas	Illinois-Iowa-Wisconsin		Central Kentucky	Illinois-Kentucky Fluorspar District
Native Metals									
Sulfur						X			
Sulfides									
Greenockite		X							
Wurtzite		X							
Covellite	X	X							
Chalcocite									
Halides									
Fluorite								X	
Oxides									
Limonite	X	X	X	X		X		X	
Hematite	X	X		X		X			
Pyrolusite		X				X			
Psilomelane						X			
Cuprite		X						X	
Melaconite				X					
Asbolite				X					
Wad						X			
Carbonates									
Cerussite		X	X	X	X	X	X		
Smithsonite		X	X		X	X	X	X	
Hydrozincite		X			X	X			
Malachite	X	X	X		X	X	X	X	
Azurite	X	X	X		X	X			
Aurichalcite		X			X				
Calcite					X			X	
Aragonite					X				
Silicates									
CalaMine		X			X	X	X		
Chrysocolla		X							
Allophane		X							

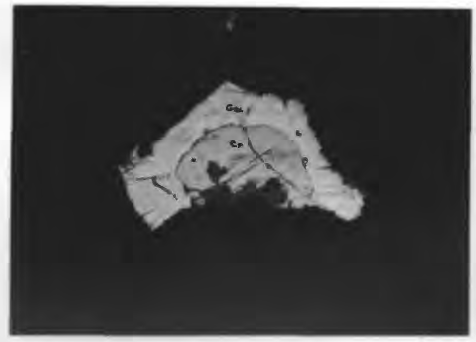
[1]Data on Missippi Valley districts taken from Bastin et al (1939, p. 107).
[2]Gray, 1953, unpublished

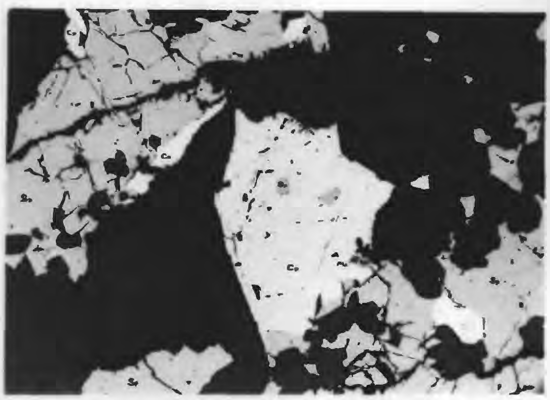
Table 3. Secondary Minerals of the Shawangunk District Compared to Similar Lead-Zinc Producing Districts[1] (continued)

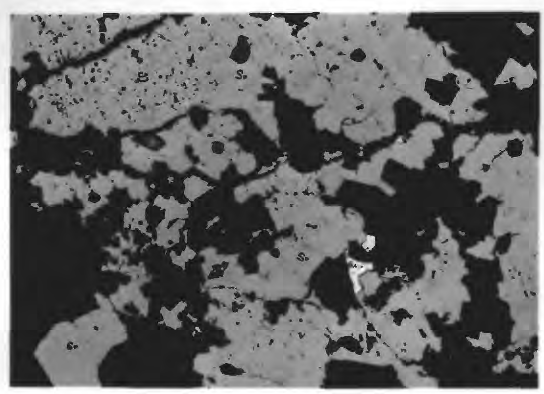
Minerals Classified	Shawangunk	Tri-State	Central Missouri	Southeastern Missouri	Northern Arkansas	Illinois-Iowa-Wisconsin	Central Kentucky	Illinois-Kentucky Fluorspar District
Sulfates								
Gypsum		X	X		X	X X	X	
Barite		X					X	
Epsomite		X			X			
Anglesite	X	X			X	X X		
Goslarite		X			X	?		
Melanterite		X				X		
Leadhillite		X						
Caledonite		X						
Linarite		X						
Chalcanthite		X						
Copiapite		X				X		
Brochanthite				X				
Bieberite				X				
Morenosite				X				

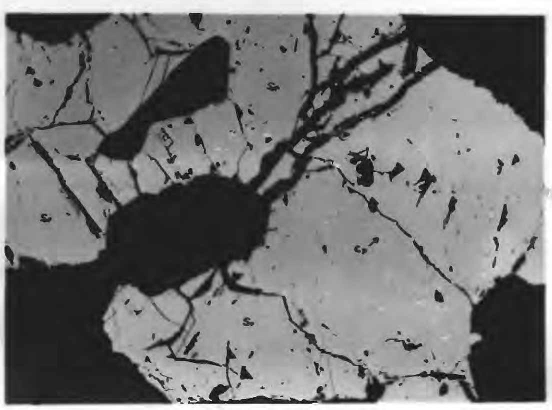
[1]Data on Missippi Valley districts taken from Bastin et al (1939, p. 107).
[2]Gray, 1953, unpublished.











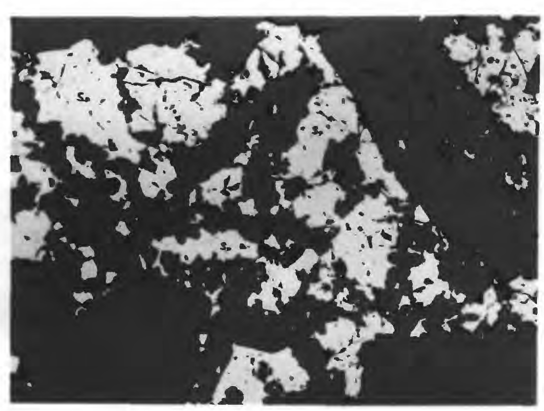
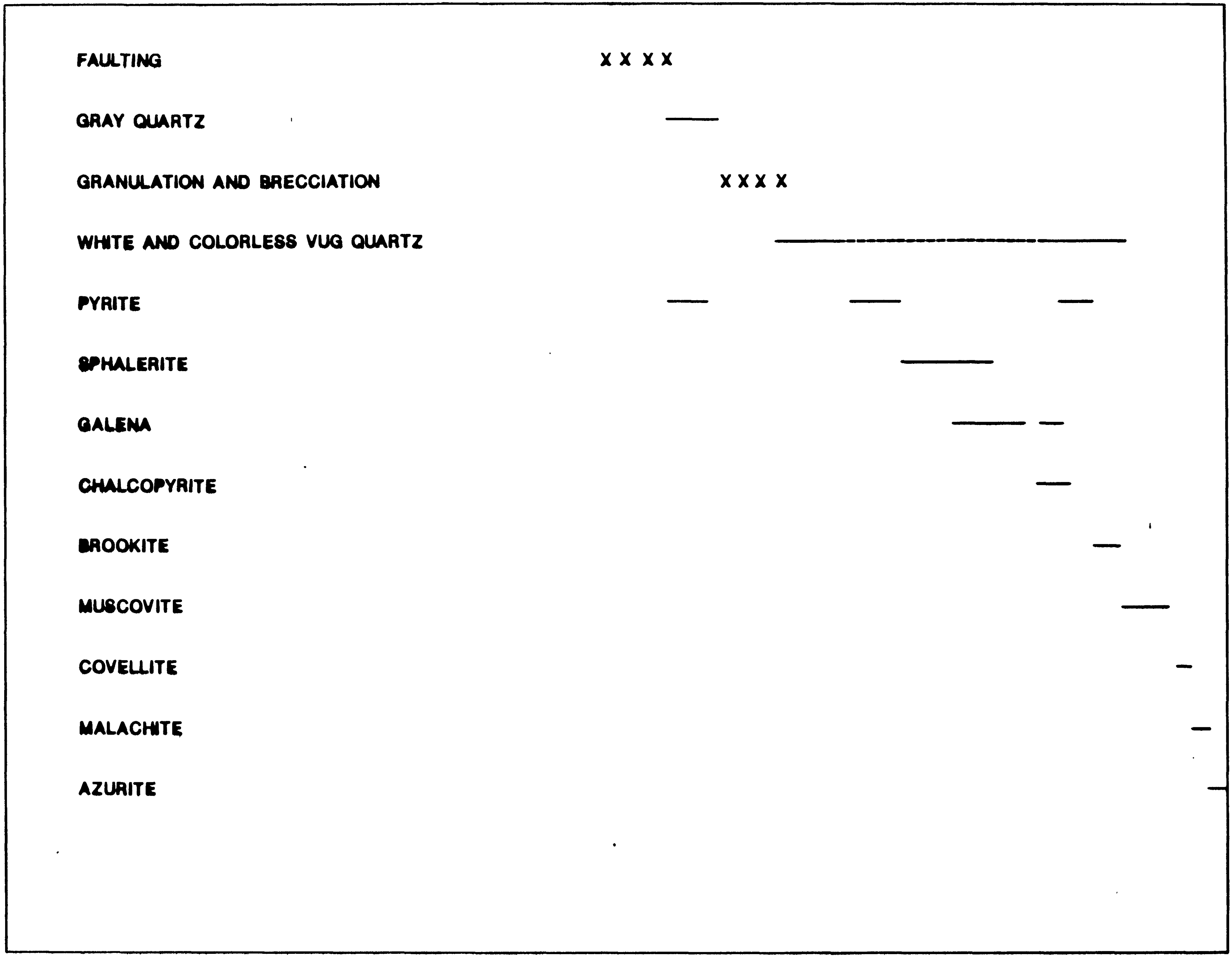


Plate 1. Caption. Photomicrographs of polished sections, Shawangunk ore district, New York

Section E-4. Upper Left	Ellenville ore body. Generally smooth boundaries between sphalerite and large chalcopyrite grain may indicate essentially simultaneous or overlapping deposition. Seriate, disconnected blebs and stringers of chalcopyrite, aligned parallel to cleavage and fractures within sphalerite, may be replacement phenomena. Concentration of chalcopyrite dots and blebs along margins of large chalcopyrite grain may also be explained by replacement — good example of the "chalcopyrite disease" of Barton. Cp = chalcopyrite. Sp = sphalerite.
Section E-5. Upper Right	Ellenville ore body. Mutual replacement of sphalerite and quartz, especially along cleavage or fracture surfaces. The automorphic outline of quartz may be a replacement texture in sphalerite. Seriate blebs of chalcopyrite aligned parallel to cleavage and fractures within sphalerite in right of field is another example of replacement of sphalerite by chalcopyrite. Sp = sphalerite.
Section S-1. Second Left	Summitville ore body. Upper level of Shawangunk Mine. Sphalerite conforms to outlines of and partly replaces idiomorphic quartz. Chalcopyrite blebs result from replacement. Supergene covellite replaces sphalerite along fractures. The fabric of lath-like covellite is visible under plane light because of strong pleochroism. Cp = chalcopyrite. Cv = covellite. Q = quartz. Sp = sphalerite.
Section S-2. Second Right	Summitville ore body. Upper level of Shawangunk Mine. Galena-chalcopyrite bleb in vein quartz suggests simultaneous primary replacement of quartz by galena and chalcopyrite. Sequential supergene replacement of chalcopyrite by covellite, malachite, and azurite represents a later stage. Az = azurite. Cp = chalcopyrite. Cv = covellite. Gal = galena. Ma = malachite. Q = quartz.
Section S-5. Third Left	Summitville ore body. Upper level of Shawangunk Mine. Chalcopyrite and sphalerite filling spaces between and generally conforming to the outlines of earlier quartz. Sphalerite, appearing as island inclusions in chalcopyrite, suggests that chalcopyrite has replaced sphalerite. Supergene covellite has selectively replaced chalcopyrite and has been followed by malachite. Cp = chalcopyrite. Cv = covellite. Ma = malachite. Q = quartz. Sp = sphalerite.
Section S-6. Third Right	Summitville ore body. Upper level of Shawangunk Mine. Sphalerite and galena filling vugs and spaces between earlier quartz may be contemporaneous; chalcopyrite and sphalerite may also be near contemporaneous. Specks of pyrite replace quartz along fractures. Cp = chalcopyrite. Gal = galena. P = pyrite. Q = quartz. Sp = sphalerite.

Section S-11. Lower Left	Summitville ore body. Upper level of Shawangunk Mine. Sphalerite occupying space between earlier vug quartz. Chalcopyrite blebs related to fracture surfaces in sphalerite may be selective replacements. Pyrite replaces quartz filling fractures in sphalerite. Cp = chalcopyrite. P = pyrite. Q = quartz. Sp = sphalerite.
Section S-13. Lower Right	Summitville ore body. Upper level of Shawangunk Mine. Sphalerite filling vugs and fractures in earlier quartz. Q = quartz. Sp = sphalerite.

PARAGENETIC SEQUENCE OF MINERALIZATION, SHAWANGUNK ORE DISTRICT, NEW YORK



III. Geochemical data from ore minerals, bedrock, and surface waters

Table 4. Significant trace-element content of Shawangunk District sulfide minerals

870219 JOB NO. SA39

LAB NO.	FIELD NO.	SAMPLE DESCRIPTION	
D-274304	S26-8	FeS_2:	Ellenville Mine, Ellenville, NY
D-274305	S26-34	ZnS:	Ellenville Mine, Ellenville, NY
D-274306	S26-35	ZnS:	Ellenville Mine, Ellenville, NY
D-274307	S26-36	$FeCuS_2$:	Ellenville Mine, Ellenville, NY
D-274308	S26-39	PbS:	Ellenville Mine, Ellenville, NY
D-274309	S26-40	PbS:	Ellenville Mine, Ellenville, NY
D-274310	S29-4	FeS_2:	From type locality of High Falls Shale
D-274311	S30	FeS_2:	From Railroad quarry, Napanoch, NY
D-274312	S54-4	ZnS:	From Shawangunk Mine, Summitville, NY
D-274313	S54-5	ZnS:	From Shawangunk Mine, Summitville, NY
D-274314	S102-1B	PbS:	From Guymard Mine, Guymard, NY
D-274315	S102-4	PbS:	From Guymard Mine, Guymard, NY
D-274316	S102-7	ZnS:	From Guymard Mine, Guymard, NY
D-274317	S102-8	ZnS:	From Guymard Mine, Guymard, NY
D-274318	S102-17	PbS:	From Guymard Mine, Guymard, NY
D-274319	S105-1	PbS:	From Washington Mine, Otisville, NY
D-274320	S105-2	PbS:	From Washington Mine, Otisville, NY
D-274321	S142-1	FeS_2:	Near Taconian unconformity surface, Rte. 17
D-274322	S200-1	PbS:	Callanhan's Quarry, Connelly, NY

NOTES: ICP ACID AND NA2O2 SINTER DIGESTIONS

Analyst: P. H. Briggs

Table 4. (continued)

LAB NO.	D-274304	D-274305	D-274306	D-274307	D-274308	D-274309	D-274310	D-274311
FIELD NO.	S26-8	S26-34	S26-35	S26-36	S26-39	S26-40	S29-4	S-30
Al %-S	0.1	<0.005	<0.005	<0.007	<0.005	<0.005	0.39	0.34
Ca %-S	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.06	<0.005
Fe %-S	56.	5.3	5.6	39.	0.02	0.007	50.	47.
K %-S	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	0.14
Mg %-S	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	0.18	0.01
Na %-S	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007
P %-S	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.005
Ti %-S	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	0.04	0.02
Mn ppm-S	<4.	27.	31.	<4.	<4.	<4.	8.	<4.
Ag ppm-S	<2.	<2.	<2.	300.	130.	400.	<2.	<2.
As ppm-S	720.	<10.	<10.	<10.	<10.	<10.	<10.	1100.
Au ppm-S	<8.	42.	42.	<8.	<8.	<8.	<8.	<8.
B ppm-S	-	-	-	-	-	-	-	-
Ba ppm-S	8.	<1.	<1.	<1.	<1.	<1.	150.	14.
Be ppm-S	<1.	<1.	<1.	<1.	<1.	<1.	<1.	<1.
Bi ppm-S	<10.	<10.	<10.	<10.	<10.	20.	<10.	<10.
Cd ppm-S	<2.	1100.	1200.	<2.	9.	7.	<2.	<2.
Ce ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	4.	12.
Co ppm-S	26.	170.	160.	10.	1.	1.	120.	52.
Cr ppm-S	5.	<1.?	<1.?	<1.	<1.	<1.	5.	8.
Cu ppm-S	17.	480.	610.	410000.	370.	49.	59.	85.
Eu ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Ga ppm-S	<4.	130.	150.	<4.	<4.	<4.	<4.	<4.
Ge ppm-S	-	-	-	-	-	-	-	-
Ho ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	<4.	<4.
La ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	5.
Li ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	3.	<2.
Mo ppm-S	3.	<2.	<2.	3.	<2.	<2.	3.	2.
Nb ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	<4.	<4.
Nd ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	<4.	<4.
Ni ppm-S	78.	4.	3.	14.	<2.	2.	260.	57.
Pb ppm-S	68.	230.	230.	150.	780000.	770000.	130.	72.
Sc ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Sn ppm-S	<10.	20.	80.	<10.	<10.	<10.	<10.	<10.
Sr ppm-S	11.	<2.	<2.	<2.	<2.	<2.	130.	6.
Ta ppm-S	<40.	<40.	<40.	<40.	<40.	<40.	<40.	<40.
Th ppm-S	6.	<4.	<4.	<4.	<4.	<4.	4.	6.
U ppm-S	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.
V ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
W ppm-S	-	-	-	-	-	-	-	-
Y ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Yb ppm-S	<1.	<1.	<1.	<1.	<1.	<1.	<1.	<1.
Zn ppm-S	11.	740000.	720000.	910.	130.	46.	27.	8.
Zr ppm-S	-	-	-	-	-	-	-	-

SA39LS

Table 4. (continued)

LAB NO.	D-274312	D-274313	D-274314	D-274315	D-274316	D-274317	D-274318	D-274319
FIELD NO.	S54-4	S54-5	S102-1B	S102-4	S102-7	S102-8	S102-17	S105-1
Al %-S	0.32	<0.33	<0.005	<0.05	<0.21	<0.08	<0.005	0.009
Ca %-S	<0.005	<0.005	<0.005	<0.005	<0.009	<0.005	<0.005	<0.005
Fe %-S	2.5	3.0	0.06	0.24	2.3	4.4	0.30	0.03
K %-S	<0.12	<0.13	<0.05	<0.05	<0.10	<0.05	<0.05	<0.05
Mg %-S	0.009	<0.01	<0.005	<0.005	0.02	0.008	<0.005	<0.005
Na %-S	0.007	0.008	<0.005	<0.005	0.006	0.005	<0.005	<0.005
P %-S	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ti %-S	0.01	<0.01	<0.005	0.006	0.02	0.006	<0.005	<0.005
Mn ppm-S	21.	26.	<4.	<4.	34.	63.	<4.	<4.
Ag ppm-S	<2.	<2.	150.	150.	11.	5.	160.	200.
As ppm-S	<10.	<10.	<10.	<10.	20.	<10.	<10.	<10.
Au ppm-S	18.	26.	<8.	<8.	21.	40.	<8.	<8.
B ppm-S	-	-	-	-	-	-	-	-
Ba ppm-S	11.	15.	3.	4.	19.	9.	<1.	<1.
Be ppm-S	<1.	<1.	<1.	<1.	<1.	<1.	<1.	<1.
Bi ppm-S	<10.	<10.	10.	<10.	<10.	<10.	<10.	<10.
Cd ppm-S	370.	460.	7.	23.	330.	560.	41.	6.
Ce ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	4.	<4.
Co ppm-S	130.	140.	<1.	5.	57.	92.	8.	<1.
Cr ppm-S	2.	4.	<1.	2.	4.	2.	1.	1.
Cu ppm-S	110.	320.	490.	220.	860.	780.	520.	91.
Eu ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Ga ppm-S	8.	11.	<4.	<4.	<4.	17.	<4.	<4.
Ge ppm-S	-	-	-	-	-	-	-	-
Ho ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	<4.	<4.
La ppm-S	3.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Li ppm-S	22.	12.	<2.	<2.	3.	<2.	<2.	<2.
Mo ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	2.
Nb ppm-S	<4.	<4.	<4.	<4.	6.	<4.	<4.	<4.
Nd ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	<4.	5.
Ni ppm-S	2.	2.	<2.	<2.	7.	2.	<2.	<2.
Pb ppm-S	300.	200.	760000.	720000.	17000.	660.	730000.	790000.
Sc ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Sn ppm-S	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Sr ppm-S	2.	3.	<2.	<2.	3.	<2.	<2.	<2.
Ta ppm-S	<40.	<40.	<40.	<40.	<40.	<40.	<40.	<40.
Th ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	<4.	<4.
U ppm-S	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.
V ppm-S	<2.	<2.	<2.	<2.	3.	<2.	<2.	<2.
W ppm-S	-	-	-	-	-	-	-	-
Y ppm-S	<2.	<2.	<2.	<2.	5.	<2.	<2.	<2.
Yb ppm-S	<1.	<1.	<1.	<1.	<1.	<1.	<1.	<1.
Zn ppm-S	380000.	470000.	3600.	24000.	380000.	680000.	42000.	2000.
Zr ppm-S	-	-	-	-	-	-	-	-

Table 4 (continued)

LAB NO.	D-274320	D-274321	D-274322
FIELD NO.	S26-8	S26-34	S26-35
Al %-S	<0.005	0.89	0.03
Ca %-S	<0.005	0.02	7.3
Fe %-S	0.02	35.	0.38
K %-S	<0.05	0.37	<0.05
Mg %-S	<0.005	0.06	0.05
Na %-S	<0.005	0.03	<0.005
P %-S	<0.005	<0.005	<0.005
Ti %-S	<0.005	0.37	<0.005
Mn ppm-S	<4.	9.	230.
Ag ppm-S	190.	6.	210.
As ppm-S	<10.	480.	<10.
Au ppm-S	<8.	<8.	<8.
B ppm-S	-	-	-
Ba ppm-S	<1.	17.	72.
Be ppm-S	<1.	<1.	<1.
Bi ppm-S	<10.	<10.	<10.
Cd ppm-S	13.	<2.	33.
Ce ppm-S	<4.	29.	<4.
Co ppm-S	<1.	150.	2.
Cr ppm-S	<1.	13.	1.
Cu ppm-S	150	800.	2300.
Eu ppm-S	<2.	<2.	<2.
Ga ppm-S	<4.	<4.	<4.
Ge ppm-S	-	-	-
Ho ppm-S	<4.	<4.	<4.
La ppm-S	<2.	12.	2.
Li ppm-S	<2.	5.	<2.
Mo ppm-S	<2.	22.	<2.
Nb ppm-S	<4.	29.	8.
Nd ppm-S	<4.	14.	<4.
Ni ppm-S	<2.	260.	2.
Pb ppm-S	740000.	630.	640000.
Sc ppm-S	<2.	2.	<2.
Sn ppm-S	<10.	340.	<10.
Sr ppm-S	<2.	10.	130.
Ta ppm-S	<40.	<40.	<40.
Th ppm-S	<4.	8.	<4.
U ppm-S	<100.	<100.	<100.
V ppm-S	<2.	10.	<2.
W ppm-S	-	-	-
Y ppm-S	<2.	5.	3.
Yb ppm-S	<1.	1.	<1.
Zn ppm-S	1200.	68.	6900.
Zr ppm-S	-	-	-

Table 4a. Mercury content of Shawangunk district sulfide Minerals

PAGE- 1A

JOB NO.-SA39LT

	As ppm 271	Hg ppm 285	Rb ppm 294	Sb ppm 296	Se ppm 297	Au ppm 322
D-274304 S26-8 FeS_2: Ellenville Mine, Ellenville, NY		.11				
D274305 S26-34 ZnS: Ellenville Mine, Ellenville, NY		220.				
D-274306 S26-35 ZnS: Ellenville Mine, Ellenville, NY		240.				
D-274307 S26-36 $FeCuS_2$: Ellenville Mine, Ellenville, NY		1.6				
D-274308 S26-39 PbS: Ellenville Mine, Ellenville, NY		.10				
D-274309 S26-40 PbS: Ellenville Mine, Ellenville, NY		.13				
D-274310 S29-4 FeS_2 From type locality of High Falls shale		.07				
D-274311 S30 FeS_2 From Railroad Quarry, Napanoch, NY		.06				
D-274312 S54-4 ZnS: From Shawangunk Mine, Wurtsboro, NY		42.				
D-274313 S54-5 ZnS: From Shawangunk Mine, Wurtsboro, NY		55.				
D-274314 S102-1B PbS: From Guymard Mine, Guymard, NY		.46				
D-274315 S102-4 PbS: From Guymard Mine, Guymard, NY		3.3				
D-274316 S102-7 ZnS: From Guymard Mine, Guymard, NY		43.				
D-274317 S102-8 ZnS: From Guymard Mine, Guymard, NY		76.				
D-274318 S102-17 PbS: From Guymard Mine, Guymard, NY		5.8				
D-274319 S105-1 PbS: From Washington Mine, Otisville, NY		.30				
D-274320 S105-2 PbS: From Washington Mine, Otisville, NY		.23				
D-274321 S142-1 FeS_2: Near Taconian unconformity surface		.51				
D-274322 S200-1 PbS: Callanhan's Quarry, Connelly, NY		1.2				

Analyst: Carol A. Gent

Table 5. Relationship of Trace Element content in ZnS (ppm)[1]: Shawangunk Ores (Selected Elements)

Element	Ellenville		Shawangunk Mine		Guymard	
	S-26-34	S-26-35	S-54-4	S-54-5	S 102-7	S 102-8
-*Ag	<2.-4.5		7-9.		5-27	
As	<10.-80		25-30.		<10-50	
Au[1]	<5-42.		18-26		21-40	
-*Ba	<1.		11-15.		9-19.	
Be	<1.		<1.		<1.	
Bi	<10.		<10.		<10.	
*Cd	1000-1200.		370-460.		330-560.	
Ce	<4.		<4.		<4.	
*Co	160-170		130-140.		57-92.	
-*Cr	<1.-50		180-400		50-450	
*Fe[1]	5.2-8.2%		4.2-4.6%		3.65-4.25%	
*Ga	130-150		8-11.		<4-17	
*Hg	210-240		42-55		43-76	
Le	<2.		<2-3.		<2.	
**Li	<2.		<12-22.		<2.	
***Mn	27-31.(Cd:Mn=38.6)		21-26(Cd:Mn=17.7)		34-63(Cd:Mn=9.2)	
Mo	<2.		<2.		<2.	
Nb	<4.		<4		<4-6	
Nd	<4.		<4		<4	
**Ni	3-4.		2-25 [15-25]		2-10	
*Sb	50-70		25-40		<25-35	
Sc	<2.		<2.		<2.	
Se	<25.		<25.		<25.	
*Sn	20-80.		<10.		<10.	
Sr	<2.		2-3		<2-3	
Ta	<40.		<40.		<40.	
Te	0.53-0.57		0.30-0.66		0.27-0.53	
Th	<4.		<4.		<4.	
***Ti	<5000.		10,000		6000-20,000	
U	<100.		<100.		<100.	
*V	<2.-10.		<0.2-<5.		<5	
***Y	<2.		<2.		<2.5	
Yb	<2.		<1.		<1	

*Ellenville higher
**Shawangunk Mine higher
***Guymard higher
[1]Except Fe in % and Au in ppb

Table 5 (continued)

	New England & Pennsylvania Mines Along Triassic Fault Zone	Central Kentucky	Central Tennessee	Kentucky-Illinois	East Tennessee
-*Ag	1-2 ppm	0.5-3	0	2	2-70.
As[1]					
Au					
-*Ba	3-5 ppm	5-15,000*	150-5000**	2	3.
Be					
Bi					
*Cd	150-700 ppm	2000-20,000*	7000-20,000**	3800-6400***	10,000****
Ce					
*Co	10-200	0	0	<4	
-*Cr					
*Fe[1]	1. to 15%	0.22%, 0.1-0.3%	0.15-0.5%	1.2-4.2%	0.3%
*Ga	15-150	20-300*	50-200**	40-120.	7-70
*Hg	0	0-10,000*	0-3,000**	0	0
Le					
**Li					
***Mn	0-1500[1] ppm Cd:Mn = 0.6	0-20 Cd:Mn=500	1-7 Cd:Mn=3375.	20 Cd:Mn=255	0
Mo	0	0	0	0	
Nb					
Nd					
**Ni	0	0.15	0	4-9	0
*Sb					
Sc					
Se					
*Sn	0	0	0	0	
Sr	0	.10-500*	0-100**	0	0
Ta					
Te					
Th					
***Ti					
U	0	0-30	0-30	0	0
*V					
***Y					
Yb					

[1]Madison Mine, N.H. exceeds Shawangunk trace contents
*Central Kentucky exceeds Shawangunk trace contents
**Central Tennessee exceeds Shawangunk trace contents
***Kentucky-Illinois exceeds Shawangunk trace contents
****East Tennessee exceeds Shawangunk trace contents
$P_{T.2}$ - Trace values from Jolly and Heyl, p. F16-17, 1967

Table 6. Geochemical trends between several Shawangunk deposits[2]

1) Ellenville sphalerite has a higher trace (and major) element content of Cd, Co, Fe, Hg, Sb, and probably V than the more southwesterly Shawangunk deposits.

2) Summitville and Guymard sphalerites have higher Ag, Ba, Cr, Ti and slightly higher Mn, and Summitville may have higher Li and Ni. The highest Ag content (700 ppm) was found in Ellenville chalcopyrite, however.

3) There is a southwesterly $\delta^{34}S$ trend, making Ellenville an end-member deposit.

4) There is a southwesterly decrease in Fe content in sphalerite.

[2]for ppm values, see Tables 4 and 4a

Table 7. Significant trace element content of Shawangunk sphalerites vs. MVT sphalerites[1]

1 Shawangunk sphalerites have generally higher Fe, Ti and Ag contents.

2) MVT sphalerites have higher Cd content.

3) The central Kentucky and central Tennessee sphalerites have much higher Ba, Hg and Ga trace contents than comparable Shawangunk sphalerites.

4) In MVT sphalerites, Cd:Mn ratios are decidedly higher than those of Shawangunk sphalerites (by about two orders of magnitude).

5) The Shawangunk deposits are similar in trace-element geochemistry, e.g. in Cd:Mn ratios in sphalerite, to deposits at Wheatley, Pa and Bristol, Conn. which occur at the Triassic border faults of the Newark Series basins; but the Shawangunk sphalerites have higher Ti and Fe. In this connection, the Ellenville deposit contains small quantities of the minerals brookite and rutile, late in the paragenetic sequence.

6) Ellenville sphalerite is higher in Sn than MVT sphalerites, and comparatively higher in Hg, Sb, and Ga (but not higher than central Kentucky and Tennessee sphalerites).

7) Shawangunk and several other northern Appalachian sphalerites may be higher in Co.

[1]for comparative ppm values, see Table 5.

Table 8. Composition and significant trace-element content of shale interbeds and orthoquartzite in relation to Taconian unconformity pyrite

861015 JOB NO. SB63

LAB NO.	FIELD NO.	SAMPLE DESCRIPTION
D-275640	S26-8	Qtz-pyrite vein
D-275641	S26-9	Qtz-pyrite vein
D-275642	S26-10	Qtz-pyrite vein
D-275643	S26-13	Shale bed (Ss)
D-275644	S26-16	Qtz-pyrite vein (Ss)
D-275645	S26-19	Orthoquartzite
D-275646	S26-20	Orthoquartzite
D-275647	S26-21	Orthoquartzite
D-275648	S26-22	Orthoquartzite
D-275649	S26-23	Orthoquartzite

Analysts: J. Taggart, Ardith J. Bartel, E. Robb

Table 8. (continued)

SB63L

LAB NO.	D-275640	D-275641	D-275642	D-275643	D-275644	D-275645
FIELD NO.	S26-8	S26-9	S26-10	S26-13	S26-16	S26-19
SiO_2 %	74.4	67.9	54.9	71.0	86.5	96.9
Al_2O_3 %	0.99	0.94	1.18	14.8	0.46	1.63
Fe_2O_3 %	16.5	21.0	29.7	2.99	8.85	0.59
MgO %	<0.10	<0.10	<0.10	0.88	<0.10	<0.10
CaO %	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Na_2O %	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
K_2O %	0.22	0.21	0.34	4.79	0.06	0.46
TiO_2 %	0.04	<0.02	0.05	1.06	0.05	0.09
P_2O_5 %	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
MnO %	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
LOI 900C	8.36	10.6	15.0	3.38	4.41	0.42

LAB NO.	D-275646	D-275647	D-275648	D-275649
FIELD NO.	S26-20	S26-21	S26-22	S26-23
SiO_2 %	99.2	98.0	94.6	98.4
Al_2O_3 %	0.53	0.76	1.39	0.77
Fe_2O_3 %	0.12	0.20	2.18	0.13
MgO %	<0.10	<0.10	<0.10	<0.10
CaO %	<0.02	<0.02	<0.02	<0.02
Na_2O %	<0.15	<0.15	<0.15	<0.15
K_2O %	0.08	0.1	0.35	0.17
TiO_2 %	0.05	0.10	0.02	0.03
P_2O_5 %	<0.05	<0.05	<0.05	<0.05
MnO %	<0.02	<0.02	<0.02	<0.02
LOI 900C	0.07	0.12	1.42	0.32

Table 8. (continued) SB63L

LAB NO.	D-275640	D-275641	D-275642	D-275643	D-275644	D-275645	D-275646	D-275647
FIELD NO.	S26-8	S26-9	S26-10	S26-13	S26-16	S26-19	S26-20	S26-21
Al %-S	0.46	0.45	0.61	7.4	0.17	0.83	0.21	0.27
Ca %-S	0.006	0.008	0.01	<0.006	0.005	0.007	0.007	<0.01
Fe %-S	12.	15.	22.	1.9	6.4	0.43	0.10	0.17
K %-S	0.18	0.17	<0.26	3.5	0.06	0.35	0.08	0.09
Mg %-S	0.03	0.03	<0.04	0.48	0.01	0.04	0.01	0.02
Na %-S	0.01	0.01	0.01	<0.1	0.006	0.01	<0.008	0.01
P %-S	<0.005	<0.005	<0.005	0.009	<0.005	<0.005	<0.005	<0.005
Ti %-S	0.03	0.02	0.03	0.48	0.02	0.05	0.03	0.05
Mn ppm-S	10.	11.	6.	<54.	17.	19.	14.	16.
Ag ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
As ppm-S	180.	300.	440.	<10.	130.	<10.	<10.	<10.
Au ppm-S	<8.	<8.	<8.	<8.	<8.	<8.	<8.	<8.
B ppm-S	-	-	-	-	-	-	-	-
Ba ppm-S	68.	16.	16.	420.	33.	49.	32.	41.
Be ppm-S	<1.	<1.	<1.	2.	<1.	<1.	<1.	<1.
Bi ppm-S	<10.	<10.	<10.	<10.	<10.	<10.	<10.	<10.
Cd ppm-S	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Ce ppm-S	5.	<4.	5.	51.	<4.	5.	7.	6.
Co ppm-S	8.	9.	13.	3.	5.	<1.	<1.	<1.
Cr ppm-S	11.	9.	11.	84.	11.	19.	17.	31.
Cu ppm-S	5.	12.	18.	5.	10.	3.	6.	2.
Eu ppm-3	<2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Ga ppm-3	<4.	<4.	<4.	18.	<4.	<4.	<4.	<4.
Ge ppm-S	-	-	-	-	-	-	-	-
Ho ppm-S	<4.	<4.	<4.	<4.	<4.	<4.	<4.	<4.
La ppm-S	3.	2.	3.	29.	2.	3.	4.	3.
Li ppm-S	17.	18.	15.	17.	<2.	8.	8.	7.
Mo ppm-S	2.	<2.	<2.	<2.	<2.	<2.	<2.	<2.
Nb ppm-S	<4.	<4.	<4.	12.	<4.	<4.	<4.	<4.
Nd ppm-S	<4.	<4.	<4.	21.	<4.	<4.	<4.	<4.
Ni ppm-S	18.	30.	40.	12.	<18.	4.	<2.	<2.
Pb ppm-S	58.	35.	40.	27.	27.	15.	12.	26.
Sc ppm-S	<2.	<2.	<2.	13.	<2.	<2.	<2.	<2.
Sn ppm-S	<20.	<20.	<20.	<20.	<20.	<20.	<20.	<20.
Sr ppm-S	7.	14.	15.	31.	3.	5.	5.	5.
Ta ppm-S	<40.	<40.	<40.	<40.	<40.	<40.	<40.	<40.
Th ppm-S	<4.	<4.	4.	12.	<4.	<4.	4.	4.
U ppm-S	<100.	<100.	<100.	<100.	<100.	<100.	<100.	<100.
V ppm-S	6.	13.	7.	91.	2.	11.	3.	3.
W ppm-S	-	-	-	-	-	-	-	-
Y ppm-S	8.	<2.	<2.	12.	<2.	<2.	<2.	<2.
Yb ppm-S	<1.	<1.	<1.	3.	<1.	<1.	<1.	<1.
Zn ppm-S	65.	28.	7.	13.	16.	17.	22.	30.
Zr ppm-S	-	-	-	-	-	-	-	-

Table 8. (continued) SB63LS

LAB NO.	D-275648	D-275649
FIELD NO.	S26-22	S26-23
Al %-S	0.67	0.35
Ca %-S	0.006	0.008
Fe %-S	1.6	0.12
K %-S	0.27	0.14
Mg %-S	0.04	0.02
Na %-S	0.008	0.008
P %-S	<0.005	<0.005
Ti %-S	0.02	0.03
Mn ppm-S	11.	9.
Ag ppm-S	<2.	<2.
As ppm-S	20.	<10.
Au ppm-S	<8.	<8.
B ppm-S	-	-
Ba ppm-S	43.	35.
Be ppm-S	<1.	<1.
Bi ppm-S	<10.	<10.
Cd ppm-S	<2.	<2.
Ce ppm-S	11.	8.
Co ppm-S	1.	<1.
Cr ppm-S	20.	15.
Cu ppm-S	3.	3.
Eu ppm-3	<2.	<2.
Ga ppm-3	<4.	<4.
Ge ppm-S	-	-
Ho ppm-S	<4.	<4.
La ppm-S	6.	4.
Li ppm-S	6.	6.
Mo ppm-S	<2.	<2.
Nb ppm-S	<4.	<4.
Nd ppm-S	<4.	<4.
Ni ppm-S	6.	<2.
Pb ppm-S	17.	38.
Sc ppm-S	<2.	<2.
Sn ppm-S	<20.	<20.
Sr ppm-S	6.	5.
Ta ppm-S	<40.	<40.
Th ppm-S	<4.	<4.
U ppm-S	<100.	<100.
V ppm-S	11.	4.
W ppm-S	-	-
Y ppm-S	<2.	<2.
Yb ppm-S	<1.	<1.
Zn ppm-S	5.	36.
Zr ppm-S	-	-

TABLE 9. SHAWANGUNK LAKES AND SPRINGS: TRACE ELEMENT CONTENT BY DEPTH (1972)

				Lake Awosting (depth in feet)						Lake Minnewaska (depth in feet)				Lake Mohonk (depth in feet)			
Spring Farm Spring	Lenape Lane Watering Trough Spring	Rhododendrum Swamp Spring	Fly Brook	Sta.1 depth2	Sta.1 depth20	Sta.1 depth35	Sta.1 depth55	Sta.2 depth25	Sta.2 depth75	Sta.1 depth2	Sta.1 depth25	Sta.1 depth40	Sta.1 depth65	Sta.1 depth2	Sta.1 depth20	Sta.1 depth35	Sta.1 depth55
8-18	8-15	8-15	8-16	8-16	8-16	8-16	8-16	8-16	8-16	8-17	8-17	8-17	8-17	8-14	8-14	8-14	8-14
7.0	7.8	3.0	1.7	0.4	0.4	0.5	0.7	0.4	0.8	0.1	0.0	0.0	0.1	0.7	0.0	0.0	1.6
0.00	1.58	1.61	.50	.51	.55	.64	.69	.57	.70	.49	.44	.54	.52	.00	.00	.00	.00
.32	1.0	.02	.54	.10	.10	.09	.17	.10	.28	.02	.03	.01	.15	.02	.00	.02	1.5
.00	.06	.06	.00	.03	.00	.00	.02	.00	.07	.27	.26	.25	.25	.00	.02	.09	.70
16	28	2.4	.5	.8	.8	.9	.9	.8	.9	2.4	2.4	2.6	2.4	4.6	4.8	4.8	5.3
5.5	8.5	1.0	.0	.2	.2	.5	.2	.1	.2	.7	.7	.7	.7	1.8	1.8	1.8	2.0
.11	.18	.04	.00	.02	.00	.00	.02	.00	.00	.02	.00	.01	.02	.05	.02	.04	.05
.02	.05	.07	.02	.03	.08	.08	.11	.15	.09	.04	.23	.20	.14	.00	.02	.02	.04
2.0	3.8	.6	.3	.2	.3	.3	.2	.3	.3	.6	.6	.6	.5	.8	.8	.8	.8
.8	1.4	.9	.1	.2	.2	.2	.3	.2	.4	.4	.5	.5	.5	.8	.8	.8	.9
.22	.00	.18	.04	.27	.03	.36	.28	.00	24	.00	.19	.00	.39	.00	.21	.00	.51
		.04	.07	.06	.06	.06	.05	.04	.04	.04	.04	.04	.04				
60	116	0	0	0	0	0	0	0	0	0	0	0	0	8	10	10	20
18	19	17	5.1	9.4	9.2	9.9	9.8	9.0	8.4	13	13	13	13	13	12	12	9.6
.8	1.0	1.0	1.2	.6	.6	.7	.8	.6	.8	1.2	1.2	1.3	1.3	1.2	1.3	1.4	1.5
.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
.2	.2	5.0	.0	.4	.2	.3	.4	.3	.4	.6	.6	.5	.7	.2	.1	.5	.2
.05	.07	.08	.03	.01	.02	.02	.00	.04	.01	.01	.03	.01	.01	.03	.00	.03	.14
81	129	33	11	13	13	14	14	13	13	20	20	20	20	27	27	27	32
1.4	.3	1.6	1.1	.8	.8	1.1	1.4	.9	1.4	.7	.7	.8	1.2	.1	.1	.9	2.0
.00	.27	.22	.35	.00	.10	.00	.00	.26	.13	.29	.05	.22	.00	.13	.00	.12	.39
0	0	1	8	1	0	1	0	0	0	0	0	0	2	1	1	1	3
---	---	11.4	8.2	7.7	7.7	4.0	(3.5)	7.5	(3.)	8.0	8.5	6.5	(?)	8.5	8.0	2.5	(H_2S)
133	215	68	34	43	43	46	41	44	42	52	47	53	48	51	53	54	60
6.57	7.73	4.35	4.15	4.20	4.23	4.25	4.32	4.37	4.38	4.38	4.41	4.46	4.46	6.70	7.17	6.17	6.22
8.8	12.4	5.4	22.6	20.5	20.5	10.0	(5.)	20.0	(4.)	20.0	15.8	9.0	(4.)	21.5	13.0	6.0	(4.)

wn in milligrams per liter.
are estimated.
l samples
ds.

Written commun. from Daniel Smiley, Mohonk Preaerve., and F. J. Pearson, Jr., Northeastern Region, Water Resources Division, U.S. Geological Survey

LAB NO.	FIELD NO.	SAMPLE DESCRIPTION
D-305670	MP-1	Maratanza Lake
D-305671	MP-1-K	Maratanza Lake
D-305672	MP-2	Mohonk Lake (@ Wharf)
D-305673	MP-2-K	Mohonk Lake (@ Wharf)
D-305674	MP-3	Minnewaska Lake, North Cove
D-305675	MP-3-K	Minnewaska Lake, North Cove
D-305676	MP-4	Awosting Lake
D-305677	MP-4-K	Awosting Lake
D-305678	MP-5	Fly Brook
D-305679	MP-5-K	Fly Brook
D-305680	MP-6	Sanders Kill
D-305681	MP-6-K	Sanders Kill
D-305682	MP-7	Coxing Kill
D-305683	MP-7-K	Coxing Kill
D-305684	MP-8	Fountain Brook (@ Trapps Rd.)
D-305685	MP-8-K	Fountain Brook (@ Trapps Rd.)
D-305686	MP-9	Mossy Brook Spring
D-305687	MP-9-K	Mossy Brook Spring
D-305688	MP-10	Rhododendron Swamp Spring
D-305689	MP-10-K	Rhododendron Swamp Spring
D-305690	MP-11	North Gully Stream, Ellenville
D-305691	MP-11-K	North Gully Stream, Ellenville
D-305692	MP-4A	Awosting Lake, 1987
D-305693	MP-4A-K	Awosting Lake, 1987
D-305694	MP-5A	Fly Brook, 1987
D-305695	MP-5A-K	Fly Brook, 1987

Table 9a. Shawangunk Region: Surface-water samples for 26-element ICP analyses (HNO_3 acidified) and potassium dichromate buffered samples for mercury analyses Jules Friedman - USGS - 21-2 April 1988 (ST-98)

Field Sample No.	Water	Date	pH	Temp(F°)	Elevation (ft)	Field Sample coordinates
MP-1	Maratanza Lake	22 April	4.1	44	2250	41°4-'56"N 74°21'20"W
MP-2 MP-2K	Mohonk Lake (at wharf) 20 ft	"	6.5	46	1250	41°46'00"N 74° 8'51"W
MP-3	Minnewaska Lake	"	4.5	50	1650	41°43'41"N 74°14'17"W
MP-3K	(North Cove) surface					
MP-4 MP-4K	Awosting Lake (Outlet)	"	4.0	46	1875	41°42'10"N 74°17'02"W
MP-4a MP-4a-K	Awosting Lake	11-17-87 survived UPS shipment	4.0	44		41°42'10"N 74°17'02"W
MP-5 MP-5K	Fly Brook	"	3.8	49	1710	41°42'29"N 74°16'56"W
MP-5a MP-5a-K	Fly Brook	11-17-87 survived UPS shipment	3.8	43		41°42'29"N 74°16'56"W
MP-6 MP-6K	Sanders Kill (W.-44/55)	"	4.0	45	1190	41°44'34"N 74°15'24"W
MP-7 MP-7K	Coxing Kill (at Trapps Rd.)	"	4.9	44	960	41°43'03"N 74°13'01"W
MP-8 MP-8K	Fountain Brook (at Trapps Rd.)	"	6.2	45	980	41°43'07"N 74°13'01"W
MP-9	Mossy Brook Spring West Box	22 April	5.4	-	730	41°46'04"N 74°09'09"W
MP-10 MP-10K	Rhododendron Swamp Spring	"	3.9	35	940	41°45'41"N 74° 9'26"W
MP-11 (#2) MP-11K	North Gully Stream	"	6.6	43	460	41°42'27"N 74°23'34"W

Also: 1987:

Lab No.	D-305670	D-305671	D-305672	D-305673	D-305674	D-305675	D-305676	D-305677
Field No.	MP-1	MP-1-K	MP-2	MP-2-K	MP-3	MP-3-K	MP-4	MP-4-K
Ag ppb/s	<2.	////	<2.	////	<2.	////	<2.	////
Al ppm/s	0.4	////	<0.1	////	0.5	////	0.6	////
B ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Ba ppb/s	7.	////	25.	////	21.	////	12.	////
Be ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
Bi ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Ca ppm/s	0.81	////	4.75	////	4.55	////	1.83	////
Cd ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
Co ppb/s	<3.	////	<3.	////	<3.	////	<3.	////
Cr ppb/s	1.	////	1.	////	1.	////	1.	////
Cu ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Fe ppm/s	0.18	////	<0.05	////	0.62	////	0.11	////
Ga ppb/s	<5.	////	<5.	////	<5.	////	<5.	////
Hg ppm/s	////	<0.00016	////	<0.00016	////	<0.00016	////	<0.00016
K ppm/s	<1.	////	<1.	////	<1.	////	<1.	////
Li ppb/s	<4.	////	<4.	////	<4.	////	<4.	////
Mg ppm/s	0.22	////	1.60	////	0.94	////	0.24	////
Mn ppb/s	25.	////	44.	////	214.	////	32.	////
Mo ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Na ppm/s	0.5	////	1.2	////	0.8	////	0.5	////
Ni ppb/s	<5.	////	<5.	////	<5.	////	<5.	////
Pb ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Si ppm/s	0.23	////	<0.01	////	0.23	////	0.33	////
Sn ppb/s	<6.	////	<6.	////	<6.	////	<6.	////
Sr ppb/s	3.6	////	35.7	////	15.9	////	4.0	////
Ti ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
V ppb/s	<6.	////	<6.	////	<6.	////	<6.	////
Zn ppb/s	28.	////	8.	////	34.	////	30.	////
Zr ppb/s	<1.	////	<1.	////	<1.	////	<1.	////

Lab No.	D-305678	D-305679	D-305680	D-305681	D-305682	D-305683	D-305684	D-305685
Field No.	MP-5	MP-5-K	MP-6	MP-6-K	MP-7	MP-7-K	MP-8	MP-8-K
Ag ppb/s	<2.	////	<2.	////	<2.	////	<2.	////
Al ppm/s	0.6	////	<0.8	////	0.5	////	0.1	////
B ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Ba ppb/s	13.	////	19.	////	27.	////	34.	////
Be ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
Bi ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Ca ppm/s	0.63	////	0.45	////	1.79	////	5.58	////
Cd ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
Co ppb/s	<3.	////	<3.	////	<3.	////	<3.	////
Cr ppb/s	1.	////	1.	////	1.	////	1.	////
Cu ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Fe ppm/s	0.09	////	<0.05	////	0.05	////	<0.05	////
Ga ppb/s	<5.	////	<5.	////	<5.	////	<5.	////
Hg ppm/s	////	<0.00016	////	<0.00016	////	<0.00016	////	<0.00016
K ppm/s	<1.	////	<1.	////	<1.	////	<1.	////
Li ppb/s	<4.	////	<4.	////	<4.	////	<4.	////
Mg ppm/s	0.20	////	0.18	////	0.47	////	1.56	////
Mn ppb/s	16.	////	82.	////	77.	////	42.	////
Mo ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Na ppm/s	0.5	////	0.6	////	0.7	////	2.3	////
Ni ppb/s	<5.	////	<5.	////	<5.	////	<5.	////
Pb ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Si ppm/s	1.0	////	1.55	////	1.82	////	1.88	////
Sn ppb/s	<6.	////	<6.	////	<6.	////	<6.	////
Sr ppb/s	3.8	////	3.8	////	8.9	////	21.6	////
Ti ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
V ppb/s	<6.	////	<6.	////	<6.	////	<6.	////
Zn ppb/s	25.	////	22.	////	21.	////	10.	////
Zr ppb/s	<1.	////	<1.	////	<1.	////	<1.	////

Lab No.	D-305686	D-305687	D-305688	D-305689	D-305690	D-305691	D-305692	D-305693
Field No.	MP-9	MP-9-K	MP-10	MP-10-K	MP-11	MP-11-K	MP-4A	MP-4A-K
Ag ppb/s	<2.	////	<2.	////	<2.	////	<2.	////
Al ppm/s	0.1	////	1.4	////	0.1	////	0.3	////
B ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Ba ppb/s	53.	////	19.	////	18.	////	6.	////
Be ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
Bi ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Ca ppm/s	10.9	////	1.99	////	5.08	////	0.53	////
Cd ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
Co ppb/s	<3.	////	<3.	////	<3.	////	<3.	////
Cr ppb/s	1.	////	<1.	////	<1.	////	11.	////
Cu ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Fe ppm/s	0.05	////	0.08	////	<0.05	////	0.10	////
Ga ppb/s	<5.	////	<5.	////	<5.	////	<5.	////
Hg ppm/s	////	<0.00016	////	<0.00016	////	<0.00016	////	<0.00016
K ppm/s	1.	////	<1.	////	<1.	////	<1.	////
Li ppb/s	<4.	////	<4.	////	<4.	////	<4.	////
Mg ppm/s	2.27	////	0.88	////	1.60	////	0.14	////
Mn ppb/s	21.	////	63.	////	7.	////	20.	////
Mo ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Na ppm/s	13.1	////	0.8	////	1.4	////	0.3	////
Ni ppb/s	<5.	////	<5.	////	<5.	////	<5.	////
Pb ppb/s	<10.	////	<10.	////	<10.	////	<10.	////
Si ppm/s	1.40	////	1.89	////	2.16	////	0.08	////
Sn ppb/s	<6.	////	<6.	////	<6.	////	<6.	////
Sr ppb/s	45.9	////	12.4	////	24.3	////	2.0	////
Ti ppb/s	<1.	////	<1.	////	<1.	////	<1.	////
V ppb/s	<6.	////	<6.	////	<6.	////	<6.	////
Zn ppb/s	9.	////	38.	////	23.	////	22.	////
Zr ppb/s	<1.	////	<1.	////	<1.	////	1.	////

Lab No.	D-305694	D-305695
Field No.	MP-1	MP-1-K
Ag ppb/s	<2.	////
Al ppm/s	0.6	////
B ppb/s	<10.	////
Ba ppb/s	11.	////
Bi ppb/s	<10.	////
Ca ppm/s	0.97	////
Cd ppb/s	<1.	////
Co ppb/s	<3.	////
Cr ppb/s	60.	////
Cu ppb/s	<10.	////
Fe ppm/s	0.18	////
Ga ppb/s	<5.	////
Hg ppm/s	////	<0.00016
K ppm/s	<1.	////
Li ppb/s	<4.	////
Mg ppm/s	0.15	////
Mn ppb/s	12.	////
Mo ppb/s	<10.	////
Na ppm/s	0.5	////
Ni ppb/s	<5.	////
Pb ppb/s	<10.	////
Si ppm/s	1.39	////
Sn ppb/s	<6.	////
Sr ppb/s	3.5	////
Ti ppb/s	<1.	////
V ppb/s	<6.	////
Zn ppb/s	41.	////
Zr ppb/s	1.	////

Lab No.	D-305694	D-305695
Field No.	MP-1	MP-1-K
Ag ppb/s	<2.	////
Al ppm/s	0.6	////
B ppb/s	<10.	////
Ba ppb/s	11.	////
Bi ppb/s	<10.	////
Ca ppm/s	0.97	////
Cd ppb/s	<1.	////
Co ppb/s	<3.	////
Cr ppb/s	60.	////
Cu ppb/s	<10.	////
Fe ppm/s	0.18	////
Ga ppb/s	<5.	////
Hg ppm/s	////	<0.00016
K ppm/s	<1.	////
Li ppb/s	<4.	////
Mg ppm/s	0.15	////
Mn ppb/s	12.	////
Mo ppb/s	<10.	////
Na ppm/s	0.5	////
Ni ppb/s	<5.	////
Pb ppb/s	<10.	////
Si ppm/s	1.39	////
Sn ppb/s	<6.	////
Sr ppb/s	3.5	////
Ti ppb/s	<1.	////
V ppb/s	<6.	////
Zn ppb/s	41.	////
Zr ppb/s	1.	////

IV. Sulfide and lead isotope data

Table 10. Summation of $\delta^{34}S$% in relation to paragenesis of ore minerals in the Shawangunk, New York Ore District***

Early -->Late

Occurrence (NE to SW) (Basal Ss)	Thickness of Shawangunk Formation (Ss) in ft.	T-Pyrite	Sphalerite	Chalcopyrite	Galena	S-Pyrite	Pyrite: Post-Taconian Unconformity Surface
Connelly, NY Callanhan's Quarry N.41°54'27";W.75°59'53"	0.				+12.40 (N=1)*		
High Falls, NY Quarry at Base of Ss N.41°49'36"; W.74°07'36"	284.					+19.80 (N=1)	
Napanoch, NY R.R. Quarry N.41°44'38"; W.74°22'19"	750.	+33.00 (N=2) ±2.18				+23.96 (N=1)	
Ellenville, NY Ellenville (Ulster) Mine N.41°42'42"; W.74°23'00"	840.	+35.10 (N=1)	+25.73 (N=3)	+24.33 (N=3) ± 0.58	+22.05 (N=2)* ±0.84	±1.20	
Summitville, NY Shawangunk Mine N.41°35'42"; W.74°27'03"	1280.		+25.49 (N=18) ±0.53	+26.57 (N=4) ±1.53	+22.73 (N=16)* ±0.66		
Otisville, NY Washington Mine N.41°28'15"; W.74°33'41"	1600±		+28.00 (N=2) ±0.85		+25.25 (N=2)* ±0.21		
Guymard, NY Guymard Mine N.41°25'48"; W.74°35'30"	1600±		+27.40 (N=2) ±0.28		+25.30 (N=2)* ±9.42		
Wurtsboro, NY U.S. Hwy 17	1600±						-2.80 (N=1)
Average Values (w)		+33.67 (N=3) ±2.11	+25.05 (N=25) ±1.03	+25.61 (N=7) ±1.67	+23.12 (N=21)** ±1.17	+21.88 (N=2) ±2.94	-2.80 (N=1)

*Submitted for Pb Isotope Analyses
**Excluding Connelly, NY
***Includes Friedman, 1957; Ault and Kulp, 1960; Crawford, 1981; LeHuray, 1984; Wilbur, Mutschler, Friedman, and Zartman, 1989

Table 10a. Sulfide isotope data for the Shawangunk region by source (see also: Wilbur, S., Mutschler, F. E., Friedman, J. D., and Zartman, R.)

S-Isotopes (Friedman, 1957, p. 226-227) (sampled by Friedman)

(analyses by Yale University laboratory)

Mineral	Locality	Sample No.	S^{32}/S^{34}	[calculated] δS^{34} ($^0/00$)
FeS_2(T)	Napanoch-RR quarry	N-19	21.55	+31.09
FeS_2(S)	" "	N-21	21.70	+23.96
ZnS	Shawangunk Mine	S-17	21.74	+22.08
ZnS	" "	S-40	21.72	+23.02
$CuFeS_2$	" "	S-21	21.66	+25.85
$CuFeS_2$	" "	S-35A	21.6	+28.7
PbS	" "	S-21	21.73	+22.55
PbS	" "	S-35A	21.72	+23.02

S-Isotopes (Ault and Kulp, 1960) (sampled by Friedman)

(analyses by Columbia University laboratory)

Mineral	Locality	Sample No.	S^{32}/S^{34}	[calculated] δS^{34} ($^0/00$)
ZnS	Ellenville Mine	HS 48	21.67	+25.38
ZnS	Shawangunk Mine	HS 50	21.66	+25.85
ZnS	Shawangunk Mine	HS 51	21.65	+26.33
ZnS	Shawangunk Mine	HS 52	21.66	+25.85
$CuFeS_2$	Ellenville Mine	HSCp 38	21.67	+25.38
$CuFeS_2$	Shawangunk Mine	HCp 29	21.65	+26.33
PbS	Shawangunk Mine	HG 238	21.70	+23.96

(Le Huray, 1984)

ZnS	Shawangunk Mine	L 107		+24.9
PbS	Shawangunk Mine	L 106		+22.2

Table 11. Lead isotope composition of Shawangunk Mountain galenas

Locality (reference)	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Ulster Mine, Ellenville (1)	18.776	15.645	38.802
" (1)	18.763	15.643	38.795
" (2)	18.79	15.64	38.92
Shawangunk Mine, Wurtsboro (1)	18.718	15.653	38.812
" (1)	18.715	15.649	38.810
" (3)	18.73	15.66	38.82
" (3)	18.70	15.63	38.75
" (3)	18.70	15.63	38.76
" (4)	18.713	15.632	38.743
" (4)	18.708	15.630	38.740
Washington Mine, Otisville (1)	18.678	15.643	38.810
" (2)	18.67	15.64	38.80
Walkill Mine, Guymard (2)	18.74	15.69	39.19
Guymard Mine, Guymard (1)	18.680	15.633	38.780
" (1)	18.685	15.637	38.784
" (2)	18.90	15.82	39.35
Callanhan's quarry, Connelly (1)	18.468	15.624	38.361
Pyrite (600 + ppm Pb) at Taconian Unconformity Sample S-142-1 - 1, Rte 17, Wurtsboro, NY	18.33	15.59	38.15

References: (1) This paper, M. H. Delevaux, analyst; (2) Brown (1962); (3) Crawford (1981); (4) LeHuray (1984).

Table 10b. $\delta^{34}S^0/00$ by locality and in relation to paragenesis of Shawangunk Sulfides*

Ore Sample	Lab	Mineral	Locality	Paragenesis	S^{32}/S^{34} (Cañon Diablo) Troilite=22.21	$\delta S^{34\,0}/00$
N-19	Y	T-pyrite	Napanoch, N.Y. Quartz-sulfide vein cutting Shawangunk cgl. and High Falls shale	Later than structural deformation, vein quartz	21.55	+29.7
N-21	Y	S-pyrite	Napanoch, N.Y. Crystals and intergranular cement in sandstone	Later than cementation of sandstone	21.70	+22.9
E-4	L	sphalerite	Ellenville ore body at .360' contour	Later than early quartz, T-pyrite; contemporaneous with 1st chalcopyrite stage; generally earlier than galena and 2d chalcopyrite	21.67	+24.3
E-6	L	chalcopyrite	Ellenville ore body at .360' contour	Possibly contemporaneous with sphalerite	21.67	+24.3
S-14	L	sphalerite	Summitville ore body; upper level	Later than early quartz, T-pyrite; overlapped by galena	21.66	+24.7
S-15	L	sphalerite	Summitville ore body; upper level	Later than early quartz, T-pyrite; overlapped by galena	21.65	+25.2
S-16	L	galena	Summitville ore body; upper level	Later than early quartz T-pyrite; overlaps sphalerite and chalcopyrite of 1st stage; precedes chalcopyrite of 2d stage	21.70	+22.9
S-16gc	L	chalcopyrite with galena	Summitville ore body; upper level	Possibly 2d stage chalcopyrite	21.66	+24.7
S17	Y	sphalerite	Summitville ore body; upper level	Later than structural deformation, early quartz, T-pyrite; overlapped by galena; earlier than chalcopyrite of 2d stage	21.74	+21.2

Table 10b. (continued)

S-17A	L	sphalerite	Summitville ore body; upper level	Later than early quartz, T-pyrite; generally earlier than galena	21.74	+21.2
S-21	Y	chalcopyrite	Summitville ore body; upper level	Later than early quartz, T-pyrite; accomapnies sphalerite, galena; precedes supergene sulfides	21.66	+24.7
S-21g	Y	galena	Summitville ore body; upper level	Later than early quartz, T-pyrite; overlaps sphalerite and chalcopyrite of 1st stage;	21.73	+21.6
S-35A	Y	galena	Summitville ore body; upper level	Precedes chalcopyrite of 2d stage	21.72	+22.1
S-35Ac	Y	chalcopyrite	Summitville ore body; upper level	Later than early quartz, T-pyrite; accompanies sphalerite, galena; precedes supergene sulfides	2.65±	+25.2
S-40	Y	sphalerite	Summitville ore body; upper level	Later than structural deformation, early quartz, T-pyrite; overlapped by galena; earlier than 2d stage chalcopyrite	21.72	+22.1

*Friedman, 1957, p. 226-227

Table 11. Lead isotope composition of Shawangunk Mountain galenas

Locality (reference)	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Ulster Mine, Ellenville (1)	18.776	15.645	38.802
" (1)	18.763	15.643	38.795
" (2)	18.79	15.64	38.92
Shawangunk Mine, Wurtsboro (1)	18.718	15.653	38.812
" (1)	18.715	15.649	38.810
" (3)	18.73	15.66	38.82
" (3)	18.70	15.63	38.75
" (3)	18.70	15.63	38.76
Washington Mine, Otisville (1)	18.678	15.643	38.810
" (2)	18.67	15.64	38.80
Walkill Mine, Guymard (2)	18.74	15.69	39.19
Guymard Mine, Guymard (1)	18.680	15.633	38.780
" (1)	18.685	15.637	38.784
" (2)	18.90	15.82	39.35
Callanhan's quarry, Connelly (1)	18.468	15.624	38.361
Pyrite (600 + ppm Pb) at Taconian Unconformity Sample S-142-1 - 1, Rte 17, Wurtsboro, NY	18.33	15.59	38.15

References: (1) This paper, M. H. Delevaux, analyst; (2) Brown (1962); (3) Crawford (1981)

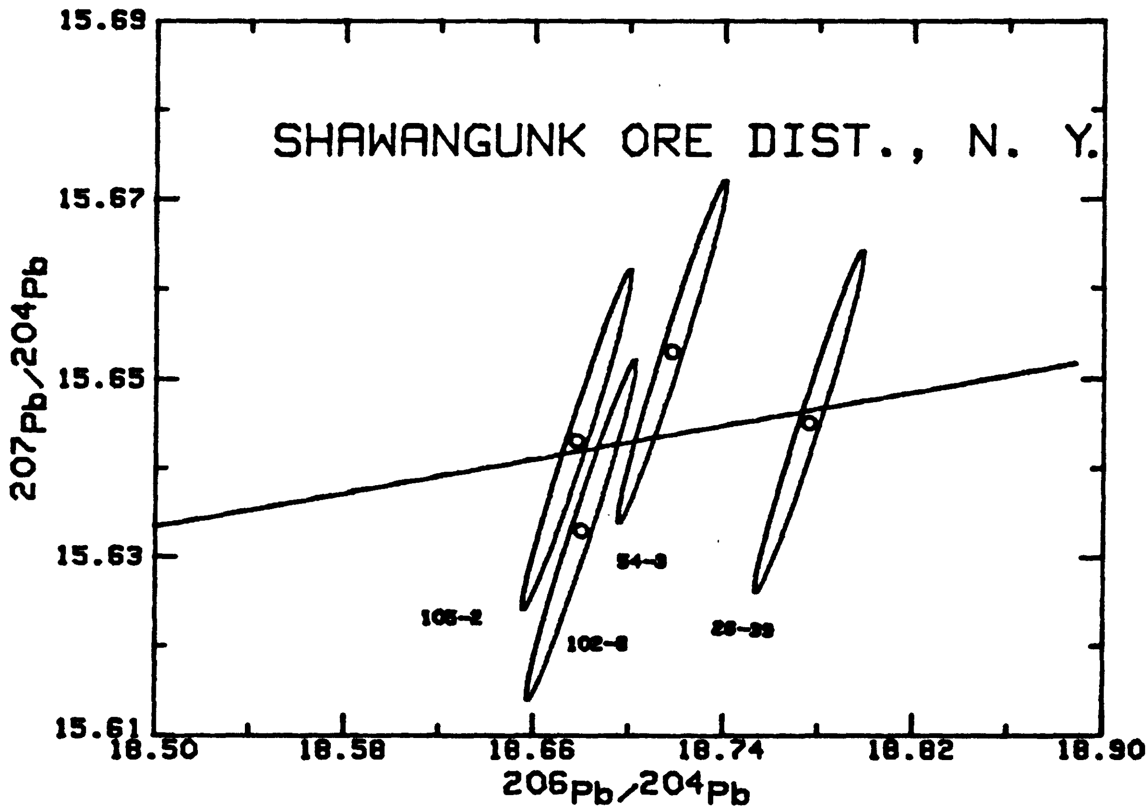


Figure 2. Lead isotopes of the Shawangunk galenas: $^{206}/Pb^{204}Pb$.

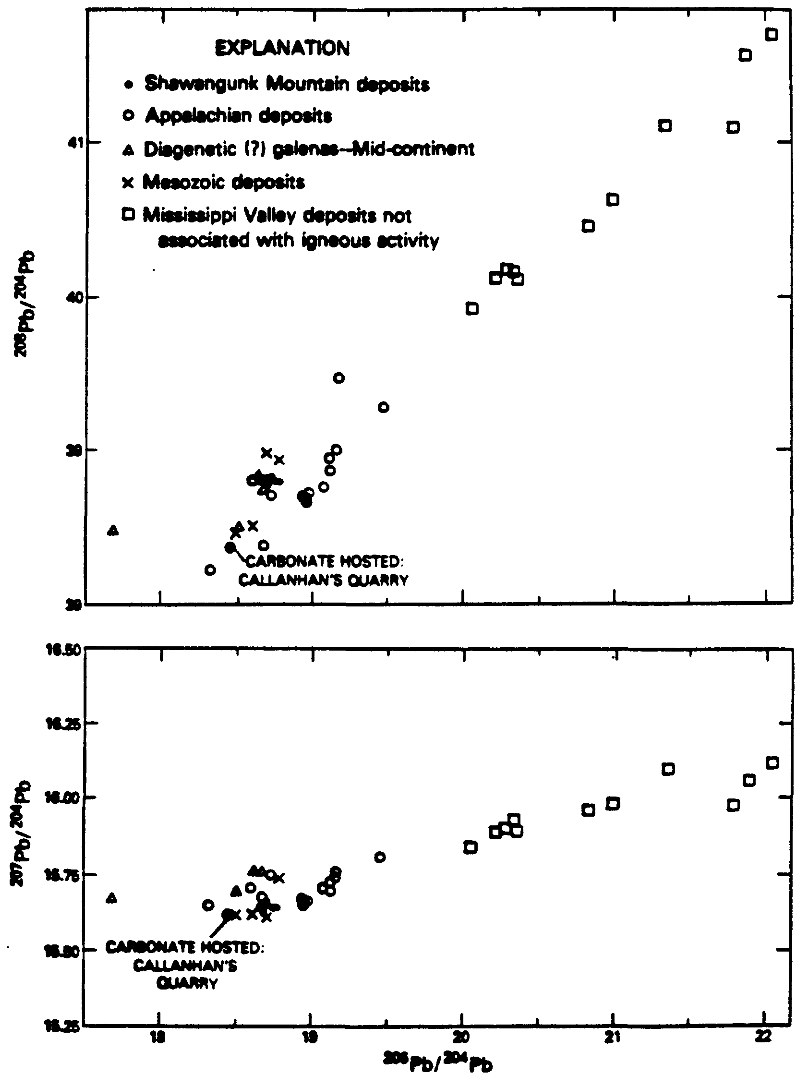


Figure 3. Lead isotope systematics of Shawangunk versus other deposit types.

V. Ultraviolet-near infrared spectral reflectance data

Ultraviolet-near infrared spectral reflectance curves of Shawangunk sulfide minerals[1], Figures 4 to 24.

Galena (Figs. 4-9,17,18): The strong peak at 0.33 μm may be a specular reflectance peak.

Pyrite (Figs. 10-13, 22-24): Spectra look more like those of geothite because the position of the 1 μm bands suggests the samples were coated with iron oxides. Alternatively, the 1.0 μm band could be due to a FeS_2 crystal field transition.

Sphalerite (Figs. 14-15, 18-21): the 2.5 μm band is probably due to a high spin $Fe2^+$ tetrahedral sulfide crystal field band. The 0.65 μ band may be due to a Co2+ crystal field transition. The band centered at 1.5 μm is a low spin Fe^{2+} crystal field band. All the other bands superposed on the absorption edge at wavelengths less than 1 μm may be due to Fe2+ crystal field bands that are spin-forbidden. The absorption edge is probably due to a S^{2-} Fe^{2+} charge transfer.

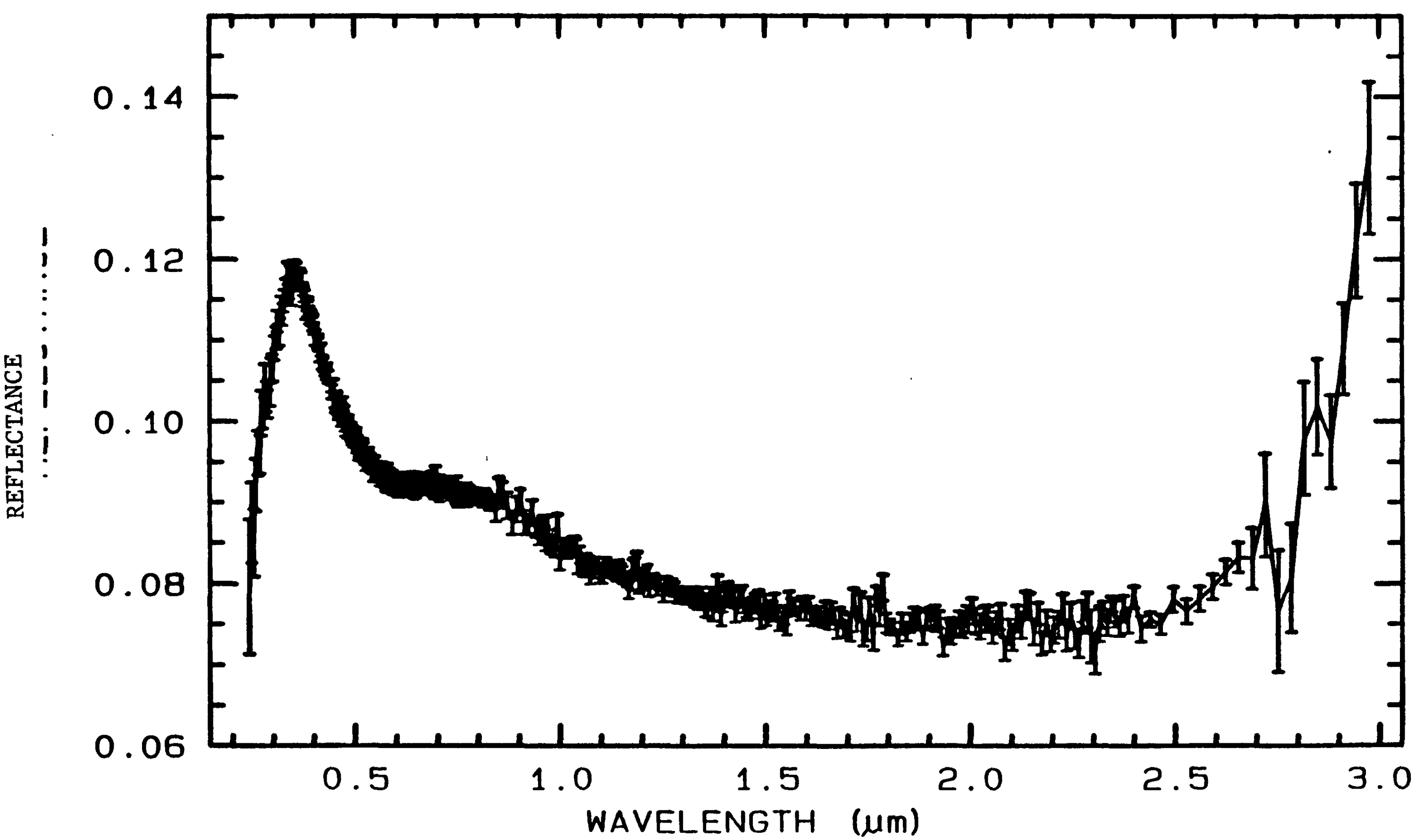
Chalcopyrite (Fig. 16): the band at 0.35 μm may be a charge transfer band of sulfur to Fe or Cu. The 0.95 μm feature is probably a Fe crystal field band.

Certain transition elements will (in certain mineral lattices) have crystal field, charge transfers, or conduction bands. These low reflectance levels are inherent to the types of minerals they occur in. The presence of Fe crystal field and charge transfer bands, because they are more intense than those due to other transition elements, will always lower the reflectance level below that of weaker bands from other transition elements. Transition elements cannot be literally translated to mean trace elements. Fe is a

[1]Analyst Gregg Swayze, December 10, 1987, USGS Denver Spectrosocpy Laboratory.

transition element and is one of the most abundant elements in most of these minerals. Further assignment of specific absorption features (to a greater degree than interpreted here) to a specific cause is complex and would take more analyses than presented here.

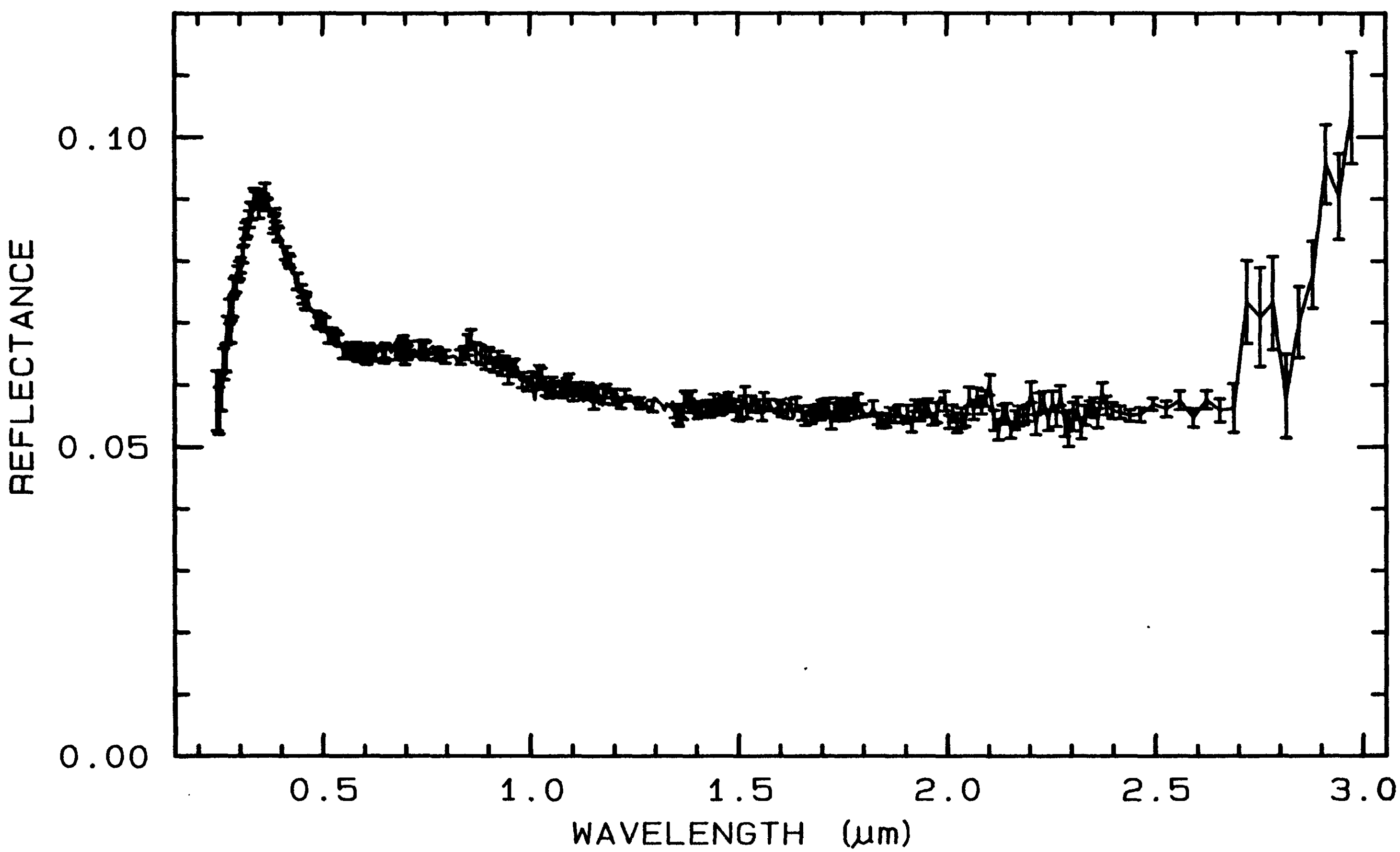
Figure 4.



Sample	200-1
Mineral	Gal(C)
Locality	C
Mode (wt. %	
Gal	80.0
Sph	1.6
Cpy	
Py	
Qtz	18.4C
Assay (wt.	
Cu	0.20
Fe	0.37
Pb	69.32
Zn	0.96
S	10.2
Trace elem	
Ag	232.8
As	50
Au(ppb)	5
Cd	25
Cr	45
Cu	1800
Hg	1.80
Mn	100
Ni	5
Pb	
Sb	200
Se	120
Te	0.06
Tl	<0.2
V	<5
Zn	9000

Galena S200-1 .2-3um 1x ABS REF spd0023 f 379 Y3p013ECg

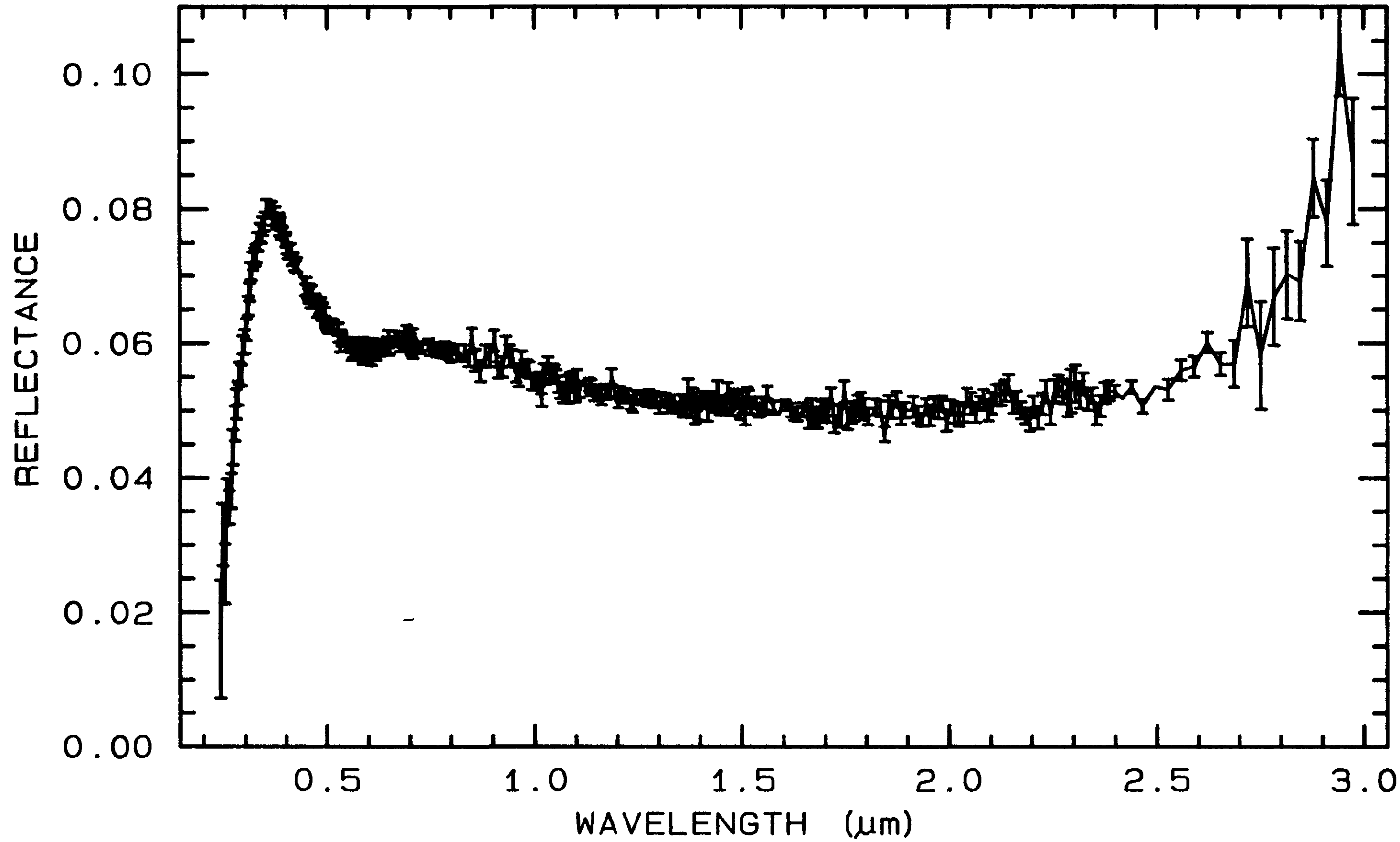
Figure 5.



Sample	102-17
Mineral	Gal(C)
Locality	G
Mode (wt. :	
Gal	92.0
Sph	6.6
Cpy	
Py	
Qtz	1.4
Assay (wt.	
Cu	0.04
Fe	0.36
Pb	79.68
Zn	4.05
S	13.7
Trace elem	
Ag	162.8
As	<25
Au (ppb)	10
Cd	35
Cr	50
Cu	450
Hg	6.00
Mn	<5
Ni	5
Pb	
Sb	200
Se	<25
Te	0.05
Tl	<0.2
V	20
Zn	

—— Galena S102-17 .2-3um 1x ABS REF spd0023 f 601 Y3p013ECg

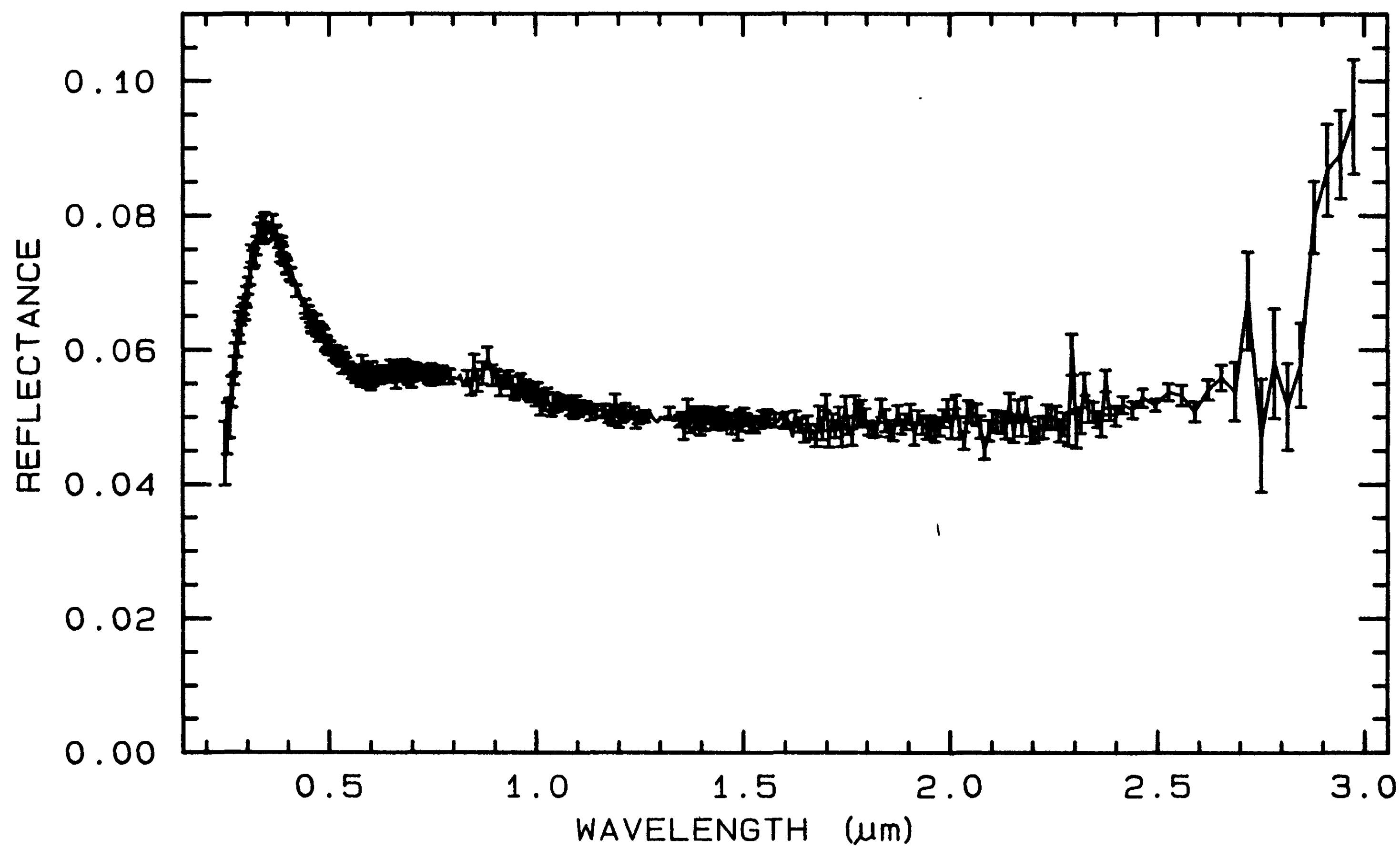
Figure 6.



Sample	105-2
Mineral	Gal(S)
Locality	W
Mode (wt.	
Gal	98.0
Sph	1.0
Cpy	
Py	
Qtz	1.0
Assay (wt	
Cu	0.04
Fe	0.10
Pb	84.56
Zn	0.69
S	12.5
Trace ele	
Ag	180.7
As	<25
Au(ppb)	5
Cd	<10
Cr	25
Cu	450
Hg	1.0
Mn	<5
Ni	<5
Pb	
Sb	100
Se	25
Te	0.17
Tl	<0.2
V	<5
Zn	7000

—— Galena S105-2 .2-3um 1x ABS REF   spd0023 f 403 Y3p013ECg

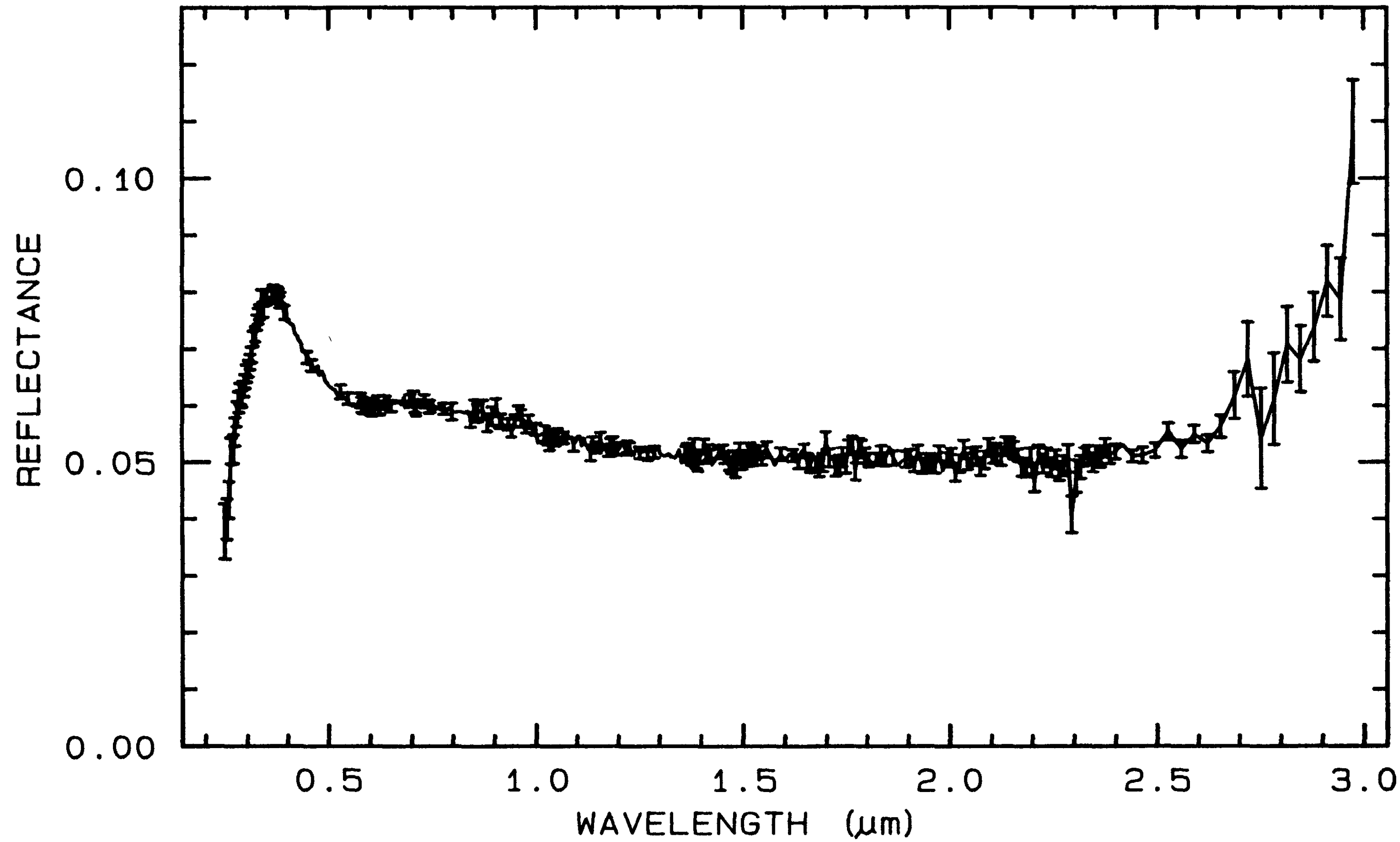
Figure 7.



Sample	102-1B
Mineral	Gal(S)
Locality	G
Mode (wt.	
Gal	95.0
Sph	1.0
Cpy	
Py	
Otz	4.0
Assay (wt	
Cu	0.04
Fe	0.17
Pb	82.37
Zn	0.66
S	13.0
Trace ele	
Ag	151.5
As	<25
Au(ppb)	<5
Cd	10
Cr	45
Cu	400
Hg	1.65
Mn	<5
Ni	10
Pb	
Sb	100
Se	45
Te	0.26
Tl	<0.2
V	10
Zn	6000

—— Galena S102-1B .2-3um 1x ABS REF spd0023 f 589 Y3p013ECg

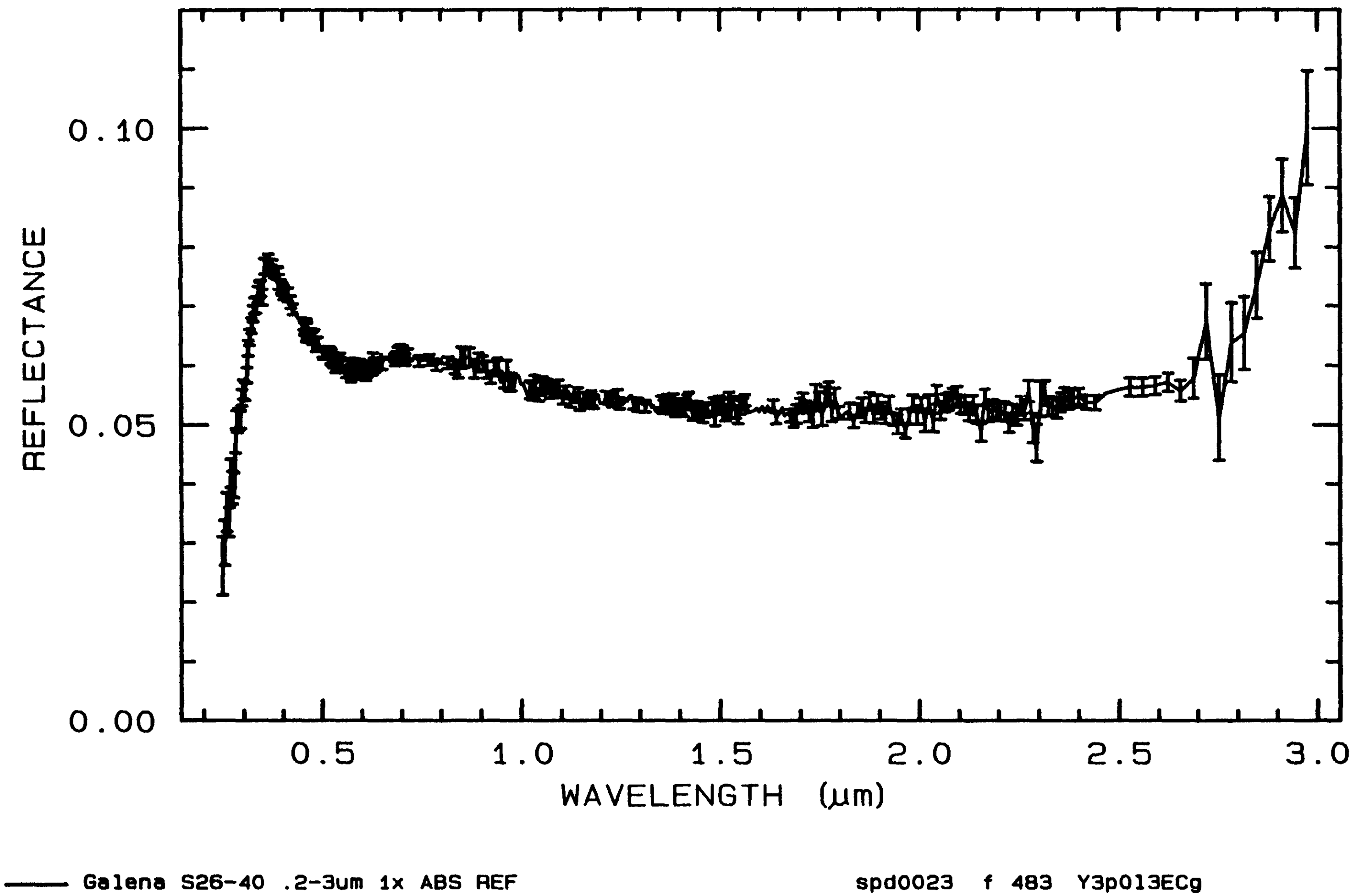
Figure 8.



Sample	102-4
Mineral	Gal(C)
Locality	G
Mode (wt.	
Gal	89.0
Sph	5.5
Cpy	
Py	
Qtz	4.5
Assay (wt.	
Cu	0.03
Fe	0.55
Pb	76.74
Zn	3.30
S	13.4
Trace elem	
Ag	151.5
As	<25
Au(ppb)	5
Cd	10
Cr	60
Cu	350
Hg	4.80
Mn	<5
Ni	10
Pb	
Sb	130
Se	<25
Te	0.09
Tl	<0.2
V	<5
Zn	

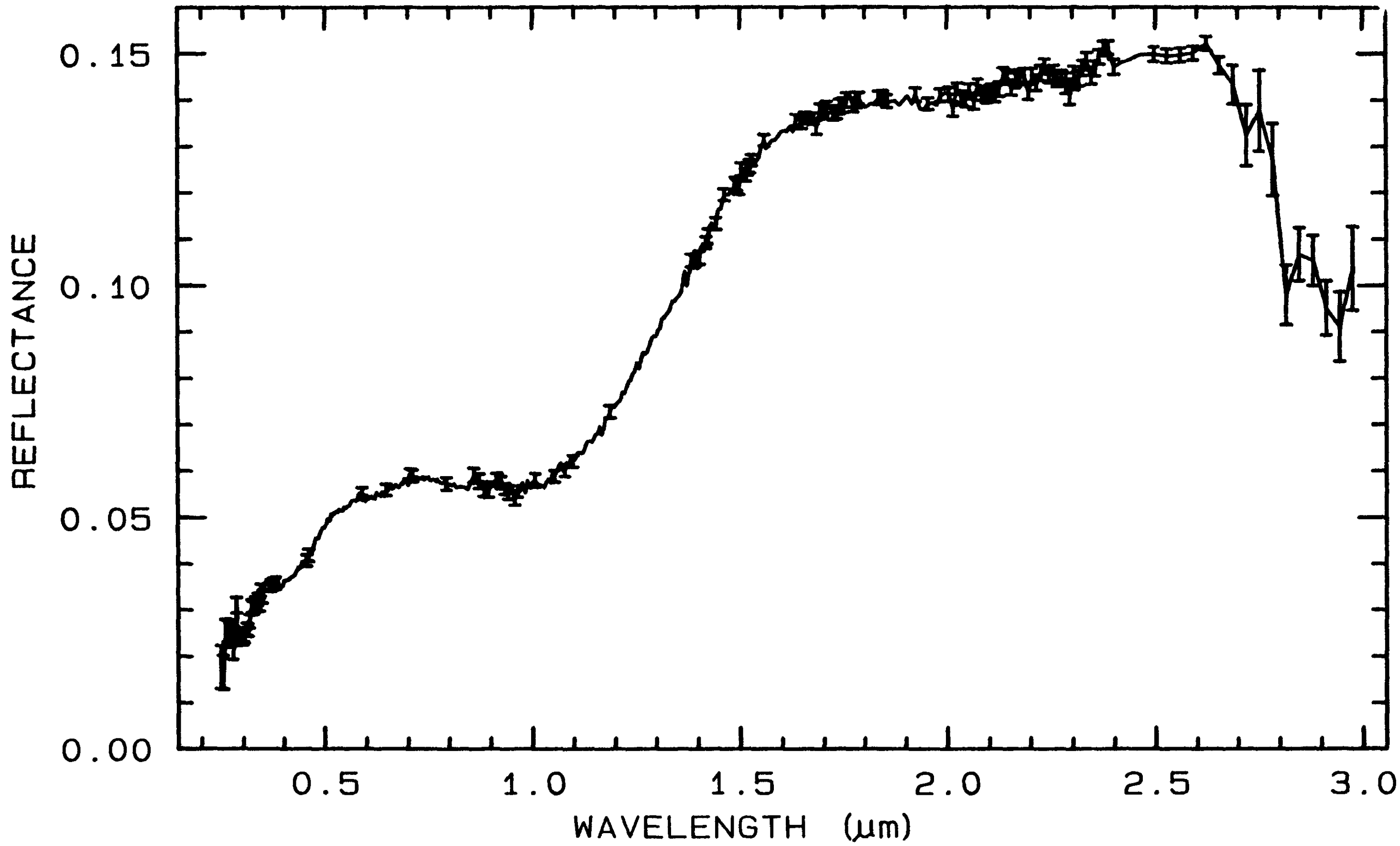
—— Galena S102-4 .2-3um 1x ABS REF   spd0023 f 528 Y3p013ECg

Figure 9.



Sample	26-40
Mineral	Gal(S)
Locality	U
Mode (wt.	
Gal	98.0
Sph	
Cpy	~1.0
Py	
Otz	1.0
Assay (wt.	
Cu	0.49
Fe	0.49
Pb	84.66
Zn	0.02
S	13.0
Trace elexcept Au)	
Ag	444
As	<25
Au(ppb)	5
Cd	<10
Cr	20
Cu	4300
Hg	0.12
Mn	<5
Ni	30
Pb	
Sb	400
Se	45
Te	0.87
Tl	0.2
V	<5
Zn	110

Figure 10.



Sample	26-8
Mineral	Py(S)
Locality	U

Mode (wt.	
Gal	
Sph	
Cpy	
Py	95.0
Qtz	5.0

Assay (wt	
Cu	<0.01
Fe	43.43
Pb	<0.01
Zn	<0.01
S	44.8

Trace ele	
Ag	<2.5
As	650
Au(ppb)	220
Cd	10
Cr	250
Cu	30
Hg	0.035
Mn	35
Ni	50
Pb	40
Sb	25
Se	25
Te	0.11
Tl	<0.2
V	20
Zn	20

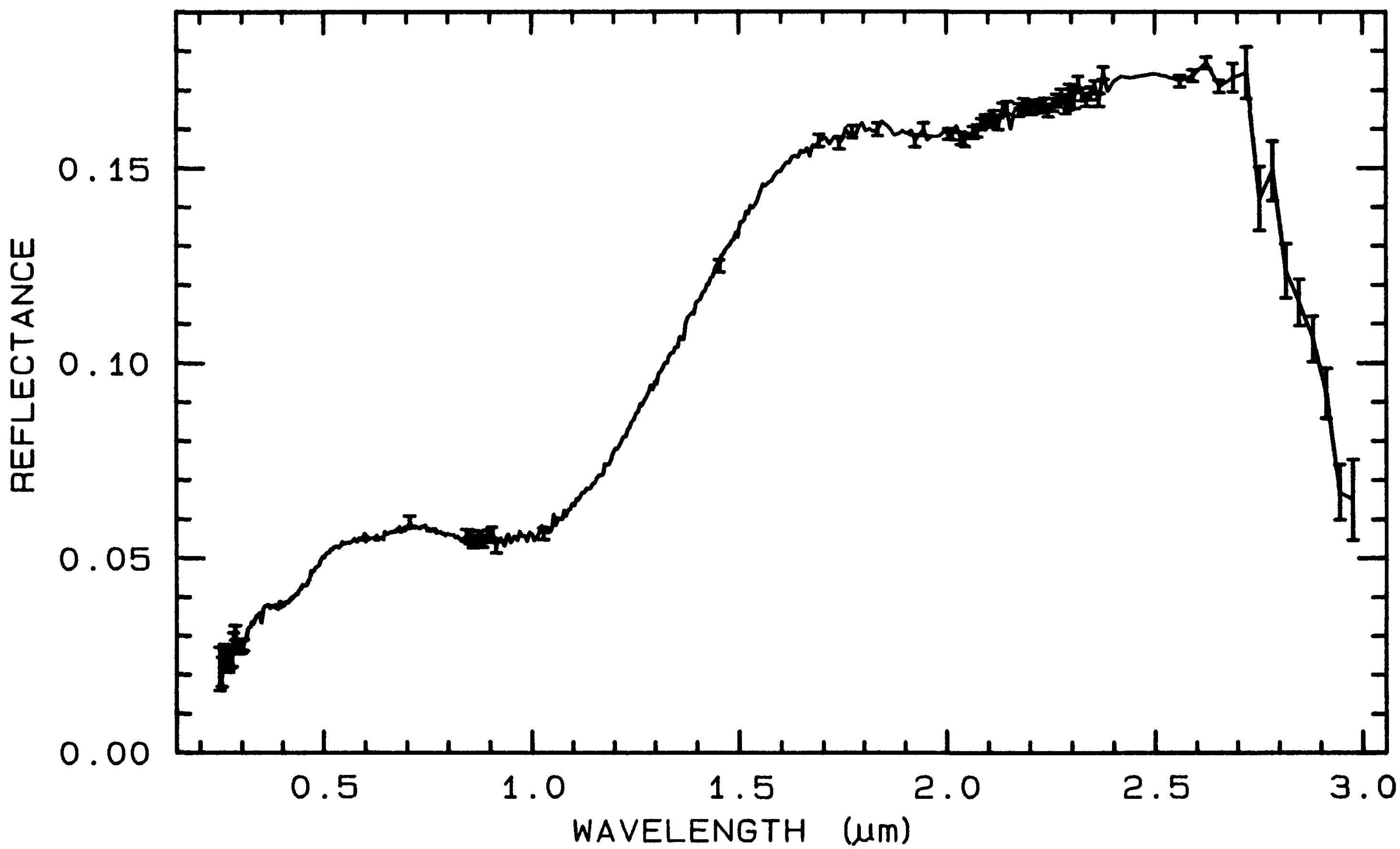
by Ledoux

— pyrite;

(C) minera

——— Pyrite S26-8 .2-3um 1x ABS REF   spd0023 f 577 Y3p013ECg

Figure 11.

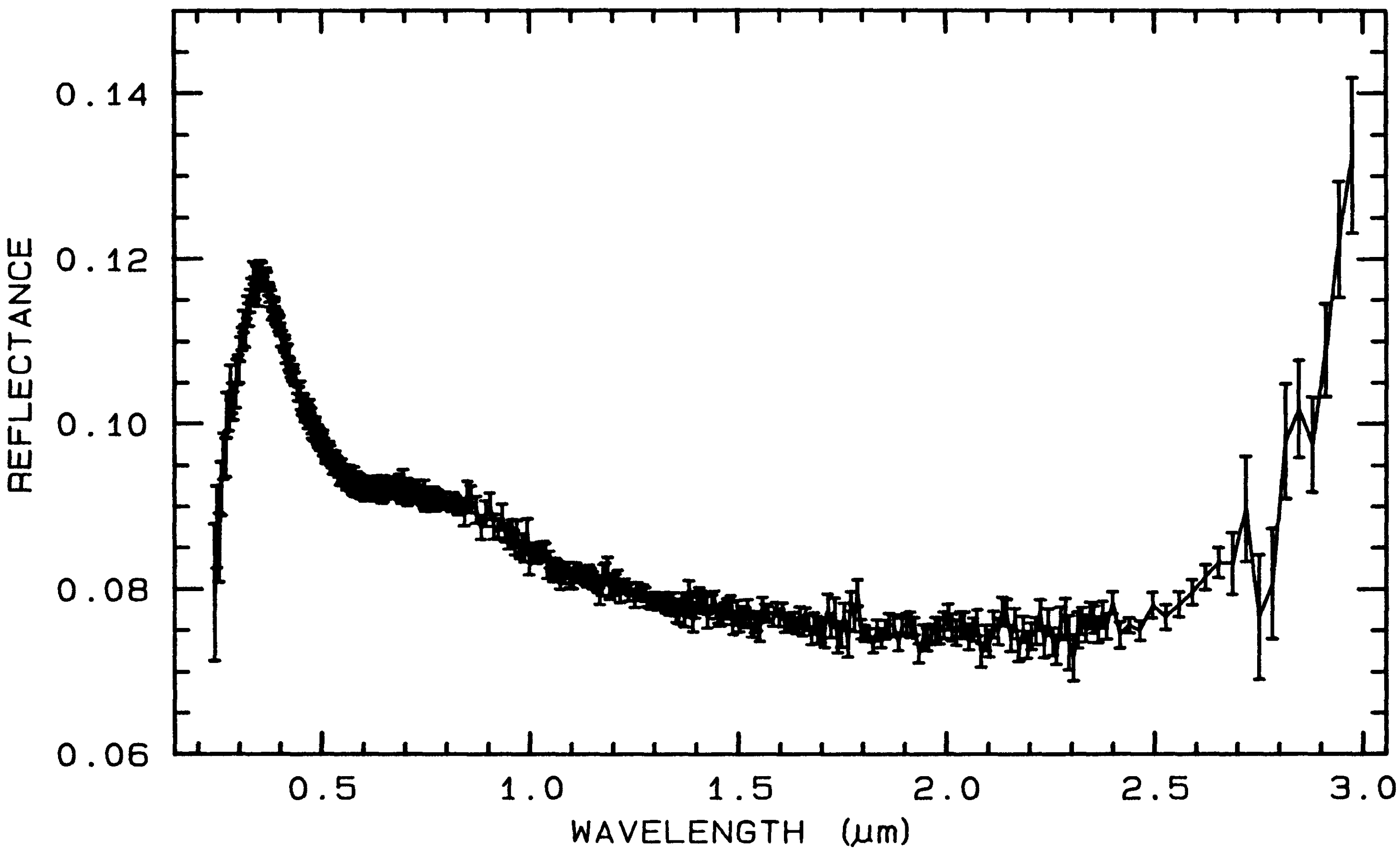


Sample	29-4
Mineral	Py(C)
Locality	HF
Mode (wt.	
Gal	6.0
Sph	
Cpy	
Py	80.0
Otz	14.0C
Assay (wt	
Cu	0.11
Fe	37.70
Pb	5.40
Zn	0.07
S	40.0
Trace ele	
Ag	8.0
As	<25
Au(ppb)	10
Cd	<10
Cr	150
Cu	800
Hg	0.335
Mn	5
Ni	150
Pb	
Sb	<25
Se	<25
Te	0.12
Tl	<0.2
V	10
Zn	600

-F, 26-M, ε

an 95% of m

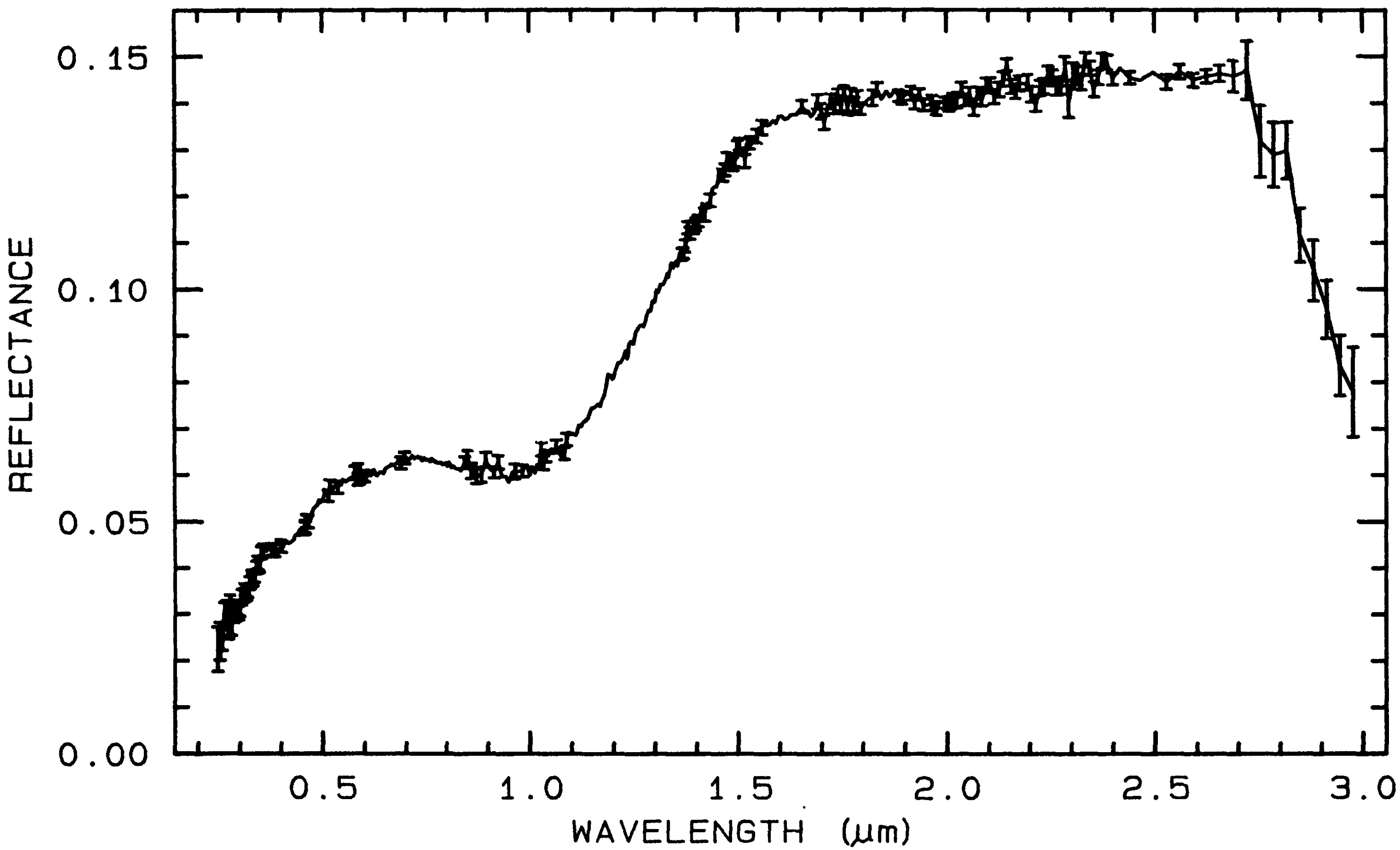
—— Pyrite S29-4 .2-3um 1x ABS REF spd0023 f 495 Y3p013ECg



Sample	200-1
Mineral	Gal(C)
Locality	C
Mode (wt. 2	
Gal	80.0
Sph	1.6
Cpy	
Py	
Otz	18.4C
Assay (wt.	
Cu	0.20
Fe	0.37
Pb	69.32
Zn	0.96
S	10.2
Trace eleme	
Ag	232.8
As	50
Au(ppb)	5
Cd	25
Cr	45
Cu	1800
Hg	1.80
Mn	100
Ni	5
Pb	
Sb	200
Se	120
Te	0.06
Tl	<0.2
V	<5
Zn	9000

—— Galena S200-1 .2-3um 1x ABS REF spd0023 f 379 Y3p013ECg

Figure 12.



Sample	30-1
Mineral	Py(C)
Locality	R
Mode (wt.	
Gal	5.5
Sph	
Cpy	
Py	84.0
Qtz	10.5
Assay (wt	
Cu	0.10
Fe	39.20
Pb	4.77
Zn	0.02
S	41.7
Trace ele	
Ag	25
As	750
Au(ppb)	40
Cd	<10
Cr	300
Cu	800
Hg	0.14
Mn	5
Ni	60
Pb	
Sb	<25
Se	<25
Te	0.11
Tl	<0.2
V	25
Zn	150

imples 26

—— Pyrite S30 .2-3um 1x ABS REF   spd0023 f 467 Y3p013ECg

Figure 13.

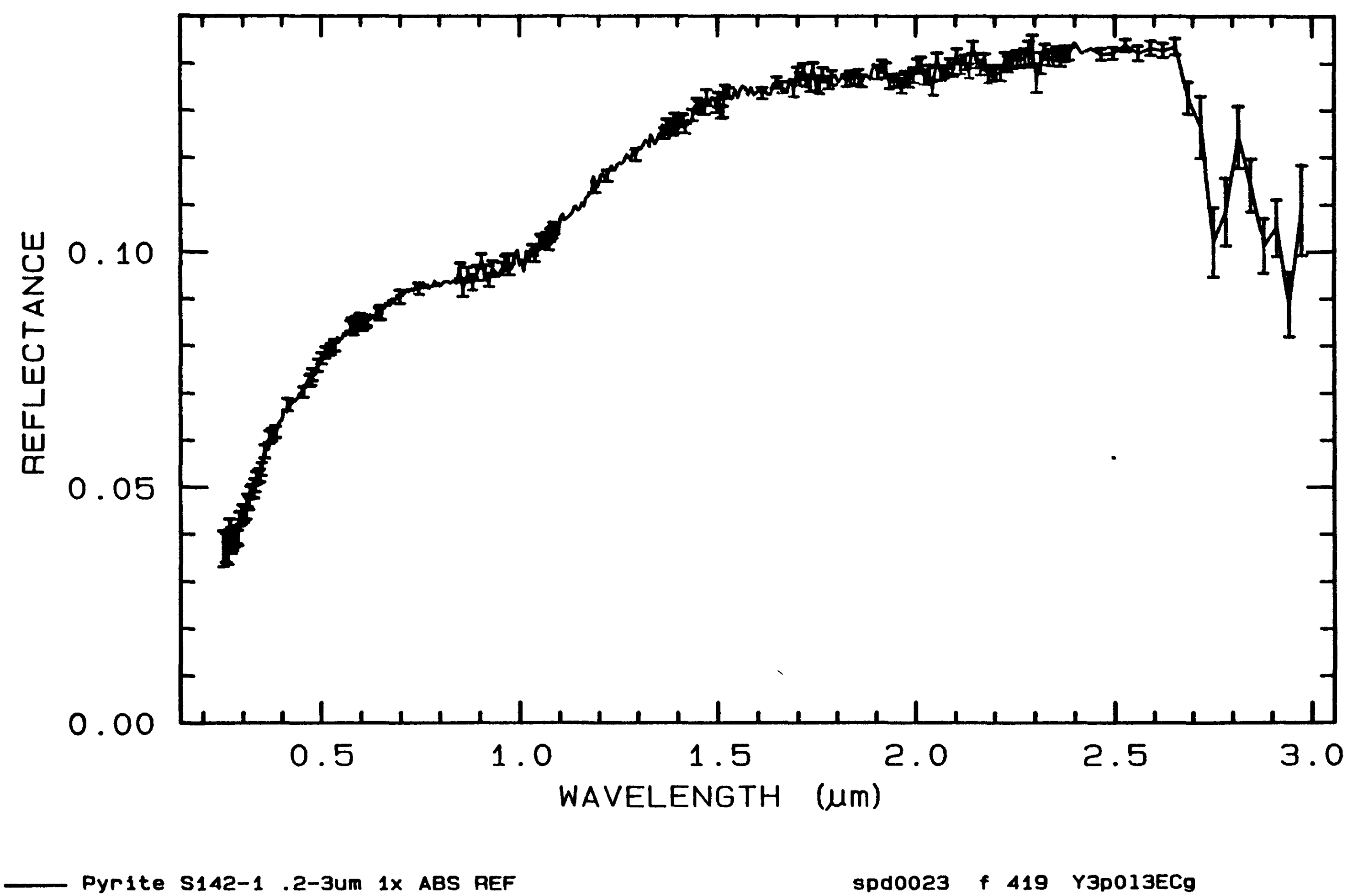
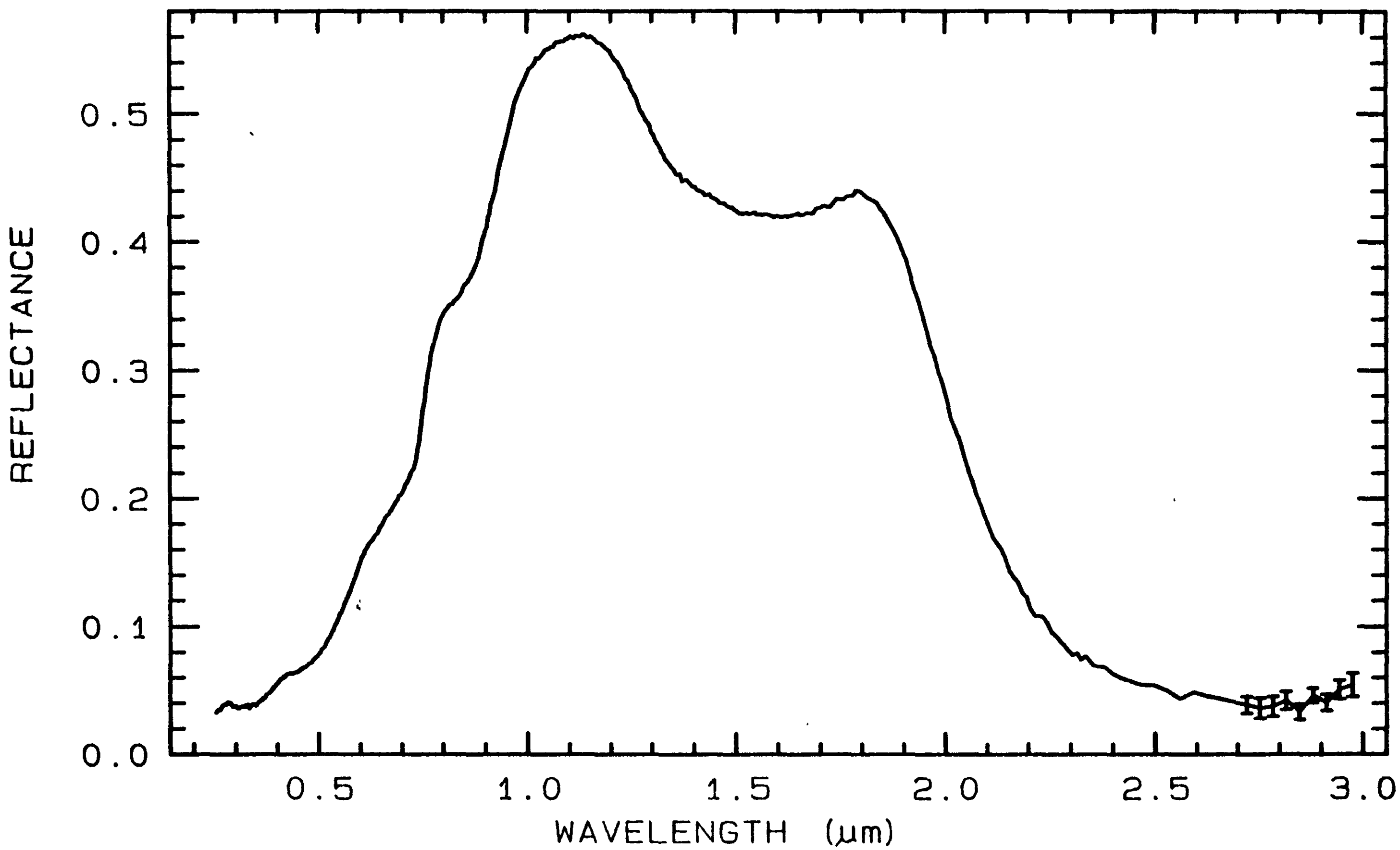

REFLECTANCE
0.10
0.05
0.00
0.5
1.0
1.5
2.0
2.5
3.0
WAVELENGTH (µm)
Pyrite S142-1 .2-3um 1x ABS REF
spd0023 f 419 Y3p013ECg

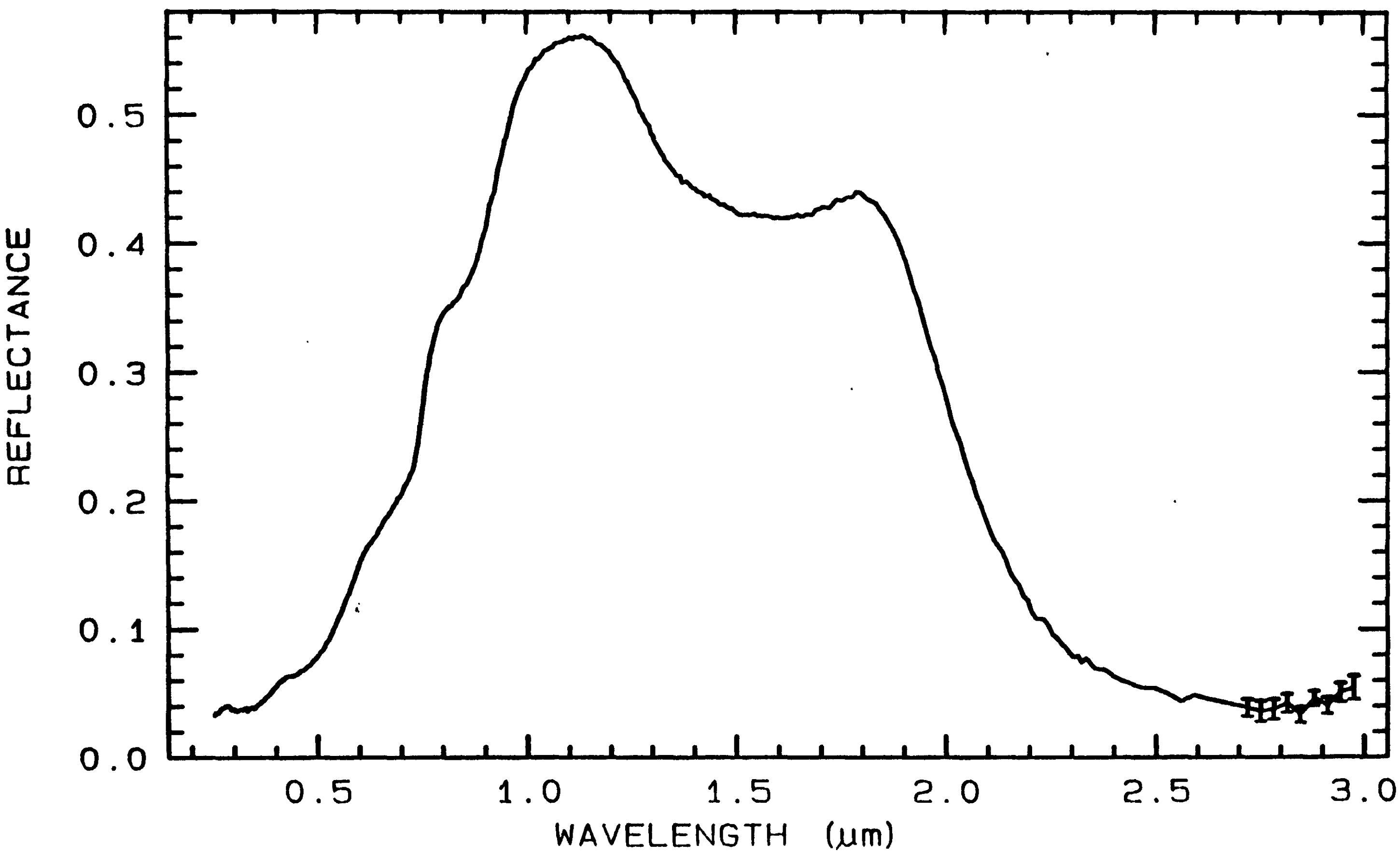
Figure 14.



Sphalerite S26-35 .2-3um 1x ABS REF spd023 f 516 U421p013ECg

Sample	26-35
Mineral	Sph(S)
Locality	U
Mode (wt.	
Gal	
Sph	95.0
Cpy	
Py	1.0
Qtz	3.0
Assay (wt.	
Cu	0.08
Fe	8.20
Pb	<0.01
Zn	55.51
S	31.9
Trace elem	
Ag	4.5
As	80
Au(ppb)	25
Cd	1100
Cr	50
Cu	450
Hg	220.0
Mn	25
Ni	<5
Pb	30
Sb	70
Se	<25
Te	0.57
Tl	<0.2
V	10
Zn	

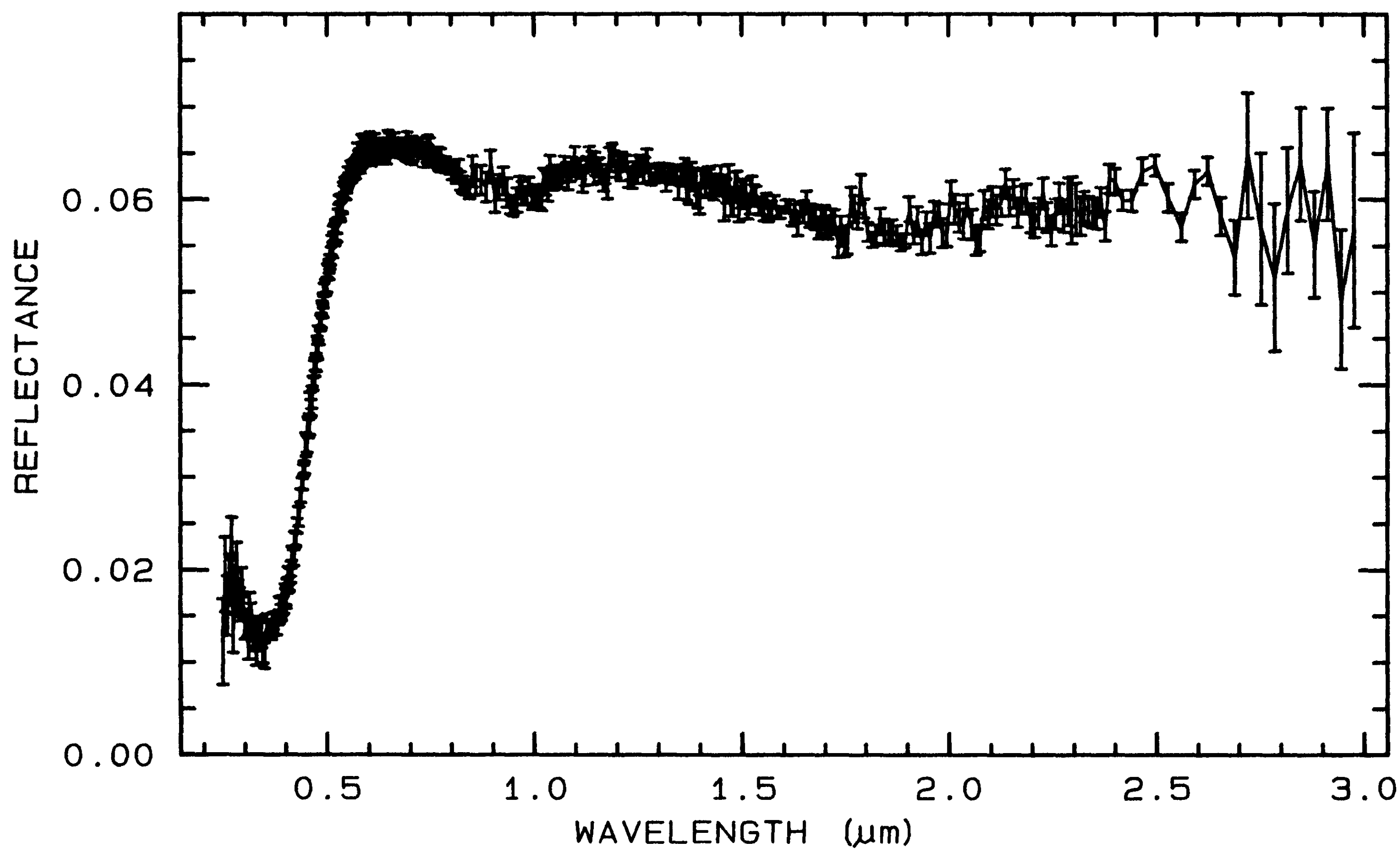
Figure 15.



Sample	26-35
Mineral	Sph(S)
Locality	U
Mode (wt.	
Gal	
Sph	95.0
Cpy	
Py	1.0
Qtz	3.0
Assay (wt.	
Cu	0.08
Fe	8.20
Pb	<0.01
Zn	55.51
S	31.9
Trace eles	
Ag	4.5
As	80
Au(ppb)	25
Cd	1100
Cr	50
Cu	450
Hg	220.0
Mn	25
Ni	<5
Pb	30
Sb	70
Se	<25
Te	0.57
Tl	<0.2
V	10
Zn	

Sphalerite S26-35 .2-3um 1x ABS REF spd023 f 516 U421p013ECg

Figure 16.



—— Chalcopyrite S26-36 .2-3um 1x ABS REF spd0023 f 565 Y3p013ECg

Sample	26-36
Mineral	Cpy(S)
Locality	U
Mode (wt.	
Gal	
Sph	1.0
Cpy	99.0
Py	
Qtz	
Assay (wt	
Cu	33.39
Fe	30.50
Pb	0.09
Zn	0.74
S	30.9
Trace ele	
Ag	371
As	<25
Au(ppb)	5
Cd	30
Cr	15
Cu	
Hg	3.30
Mn	<5
Ni	10
Pb	1000
Sb	40
Se	<25
Te	0.03
Tl	<0.2
V	<5
Zn	7500

sample S-1

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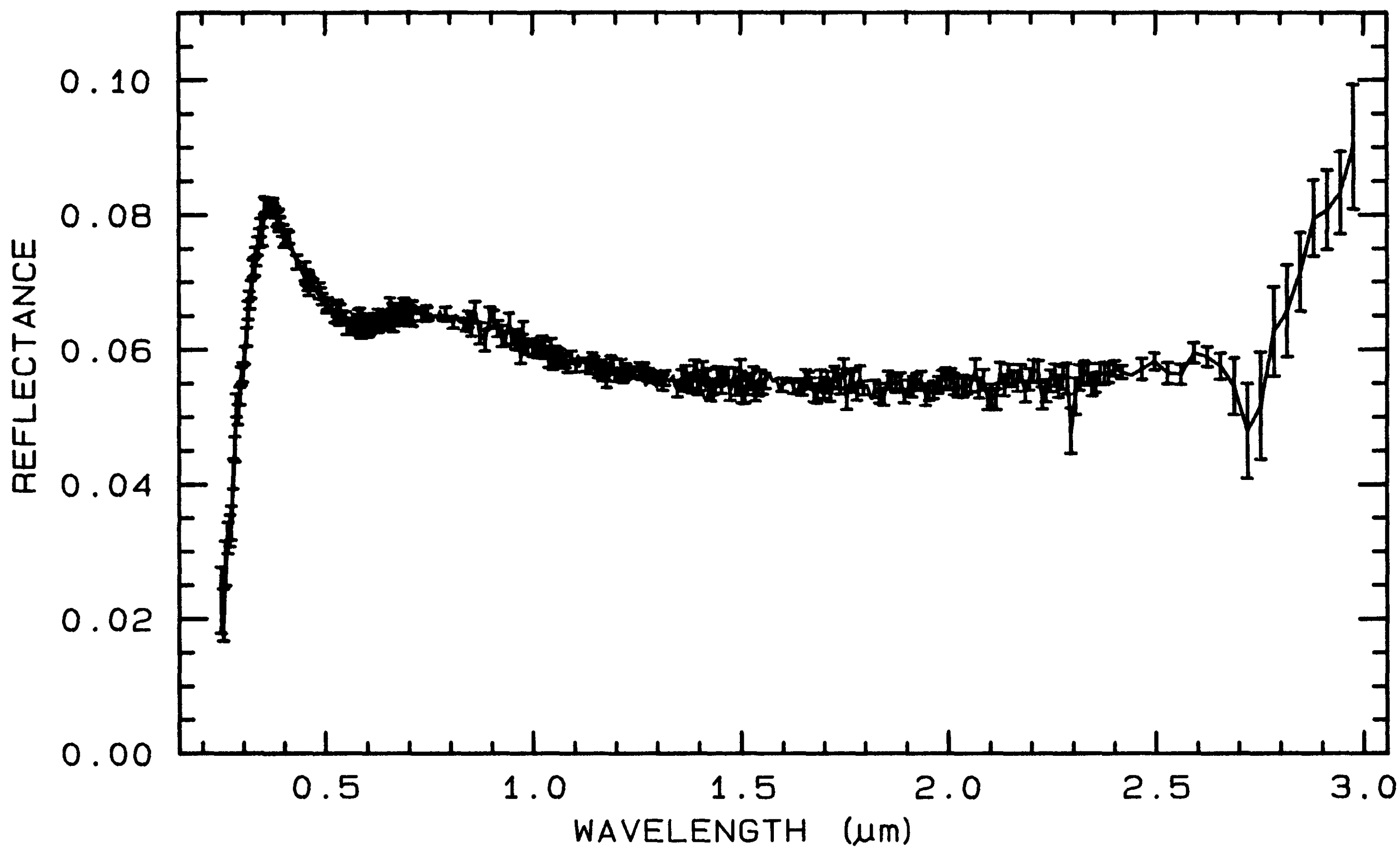
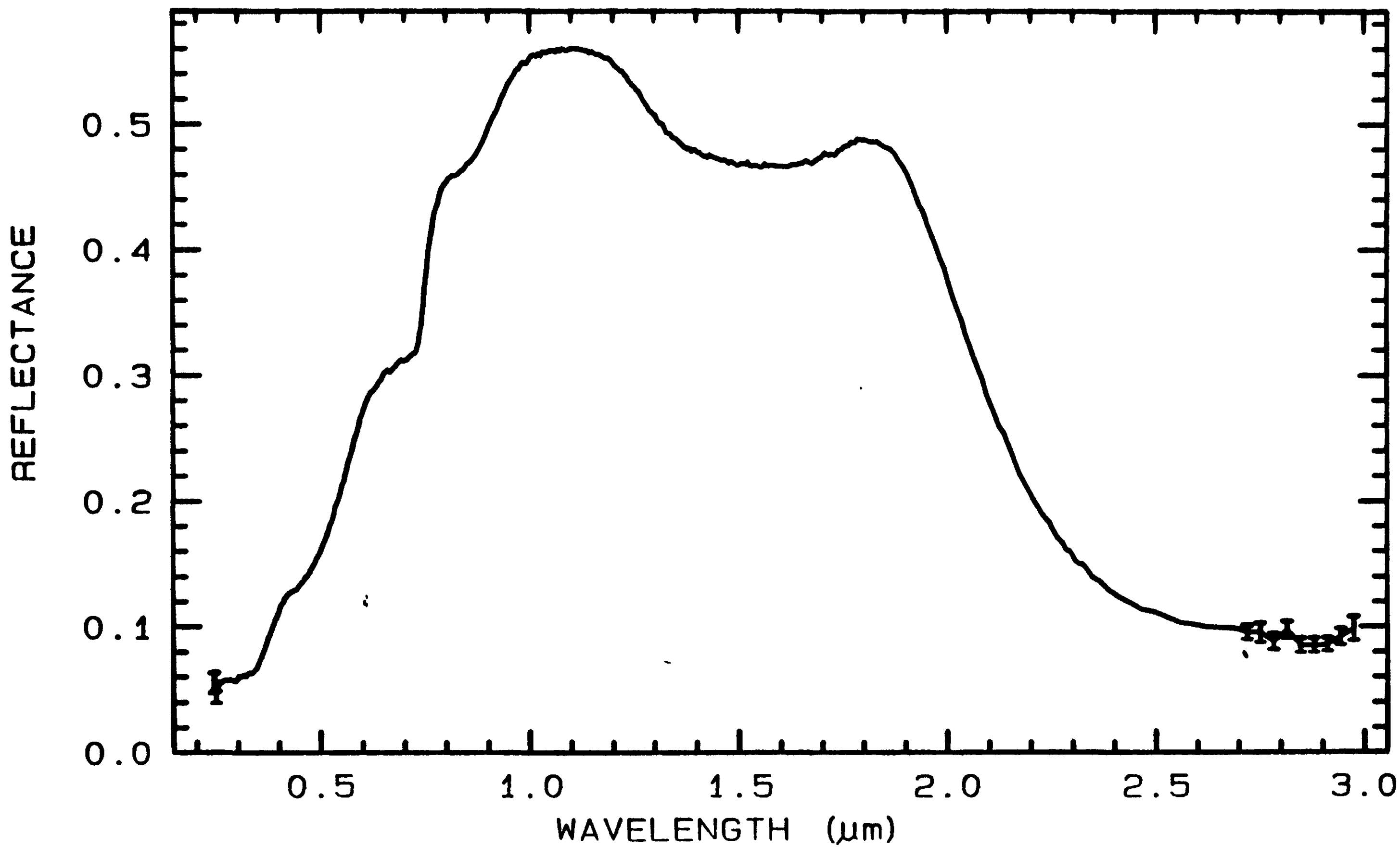
Figure 17.



—— Galena S26-39 .2-3um 1x ABS REF   spd0023 f 549 Y3p013ECg

Sample	26-39
Mineral	Gal(S)
Locality	U
Mode (wt.	
Gal	98.0
Sph	
Cpy	~1.0
Py	
Qtz	1.0
Assay (wt.	
Cu	0.45
Fe	0.49
Pb	84.61
Zn	0.05
S	12.8
Trace elem (ppm, e	
Ag	120.3
As	<25
Au(ppb)	<5
Cd	<10
Cr	10
Cu	4500
Hg	0.38
Mn	<5
Ni	<5
Pb	
Sb	100
Se	50
Te	0.39
Tl	<0.2
V	<5
Zn	500

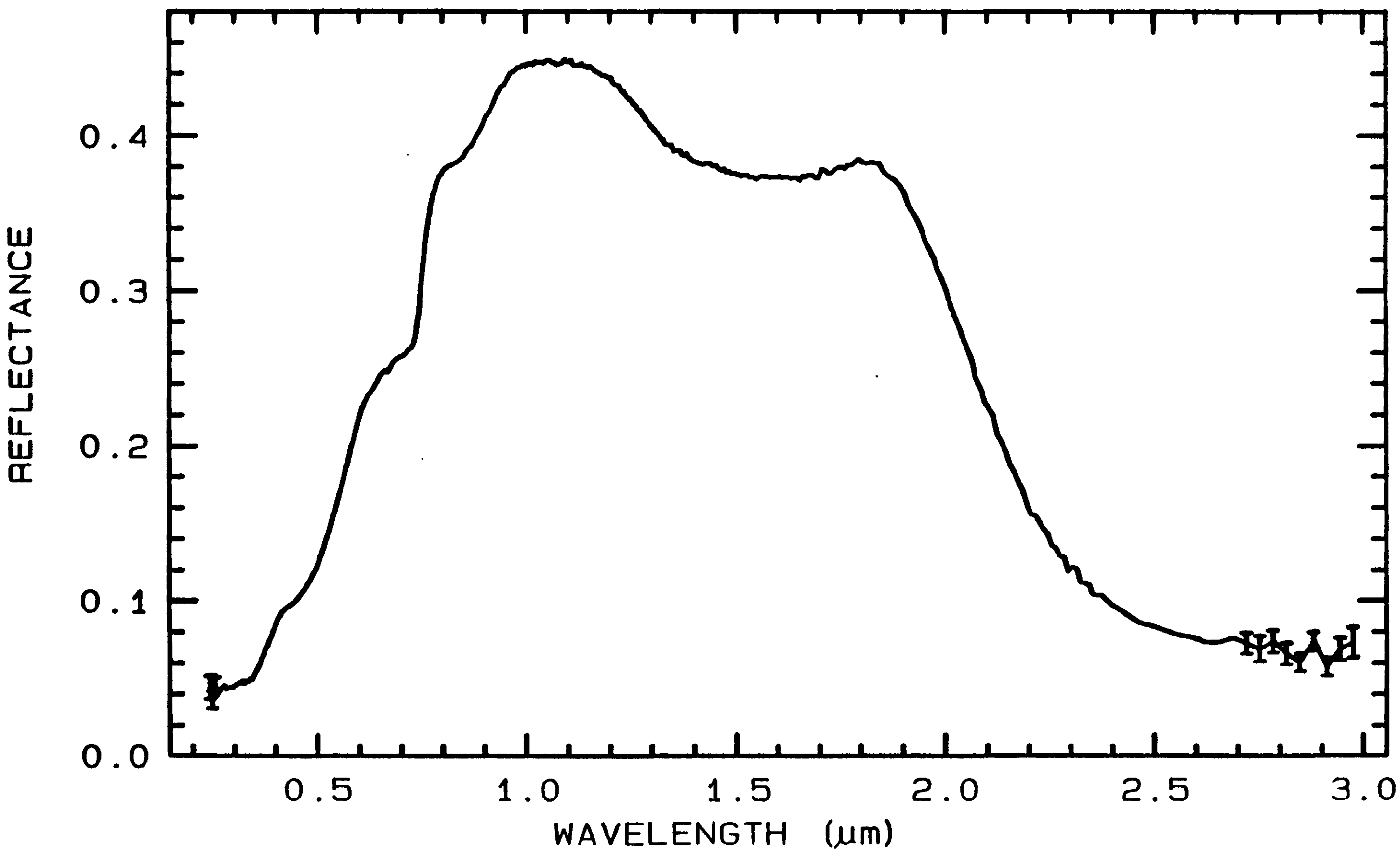
Figure 18.



Sample	54-4
Mineral	Gal(C)
Locality	S
Mode (wt.	
Gal	62.0
Sph	17.0
Cpy	
Py	11.0
Qtz	10.0
Assay (wt	
Cu	0.08
Fe	6.25
Pb	53.14
Zn	10.10
S	18.4
Trace ele	
Ag	75.4
As	100
Au(ppb)	10
Cd	110
Cr	150
Cu	750
Hg	15.0
Mn	20
Ni	15
Pb	
Sb	50
Se	250
Te	0.15
Tl	<0.2
V	15
Zn	

Galena S54-4 .2-3um 1x ABS REF spd0023 f 431 Y3p013ECg

Figure 19.

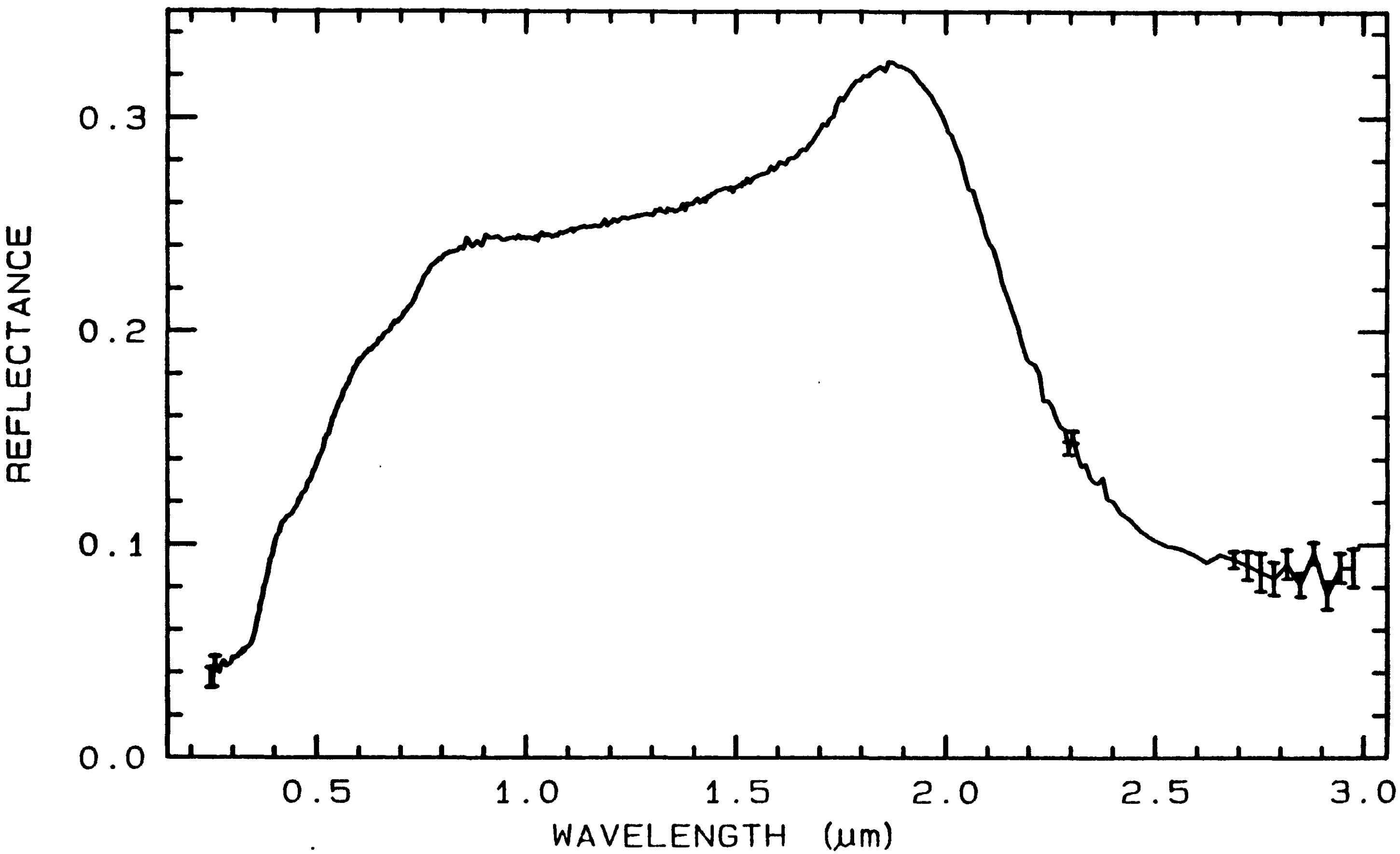


Sphalerite S54-5 .2-3um 1x ASB REF spd0023 f 391 Y3p013ECg

ıtinued)

Sample	54-5
Mineral	Sph(C)
Locality	S
Mode (wt. %)	
Gal	4.5
Sph	64.0
Cpy	
Py	
Qtz	30.0
Assay (wt. %)	
Cu	0.05
Fe	4.60
Pb	3.65
Zn	39.98
S	21.2
Trace elements (ppm,	
Ag	9
As	25
Au(ppb)	10
Cd	400
Cr	400
Cu	450
Hg	53.0
Mn	70
Ni	15
Pb	
Sb	40
Se	25
Te	0.30
Tl	0.2
V	<5
Zn	

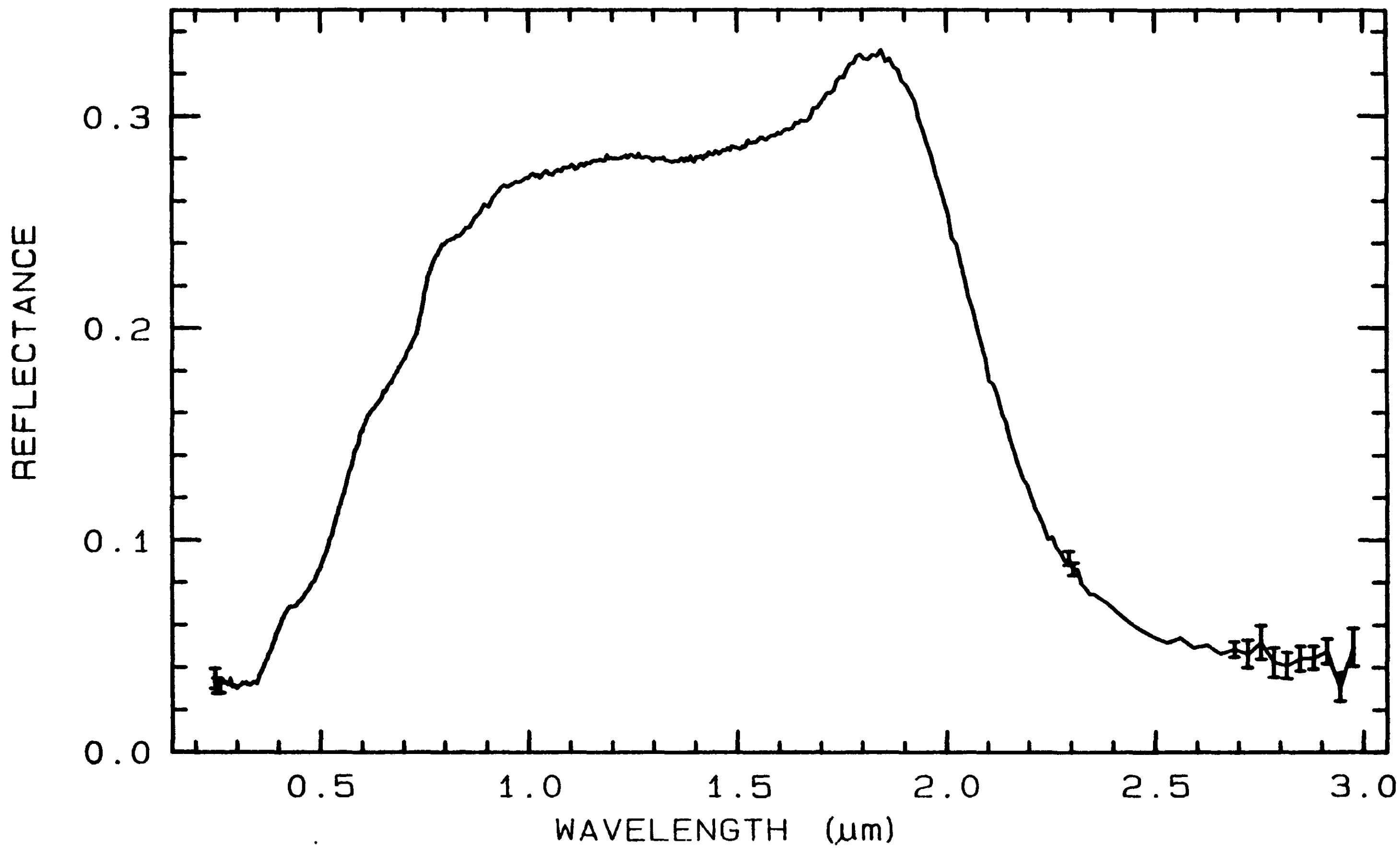
Figure 20.



Sample	102-7
Mineral	Sph(C)
Locality	G
Mode (wt.	
Gal	6.5
Sph	63.0
Cpy	0.3
Py	
Qtz	30.0
Assay (wt	
Cu	0.12
Fe	3.65
Pb	7.35
Zn	38.63
S	20.6
Trace ele	
Ag	27
As	50
Au(ppb)	10
Cd	300
Cr	450
Cu	1050
Hg	48.0
Mn	15
Ni	10
Pb	
Sb	35
Se	<25
Te	0.27
Tl	<0.2
V	<5
Zn	

Sphalerite S102-7 .2-3um 1x ABS REF spd023 f 637 U421p013ECg

Figure 21.



Sphalerite S102-8 .2-3um 1x ABS REF   spd023   f 613   U421p013ECg

Sample	102-8
Mineral	Sph(C)
Locality	G
Mode (wt.	
Gal	4.0
Sph	90.0
Cpy	
Py	
Qtz	6.0
Assay (wt.	
Cu	0.06
Fe	4.25
Pb	3.35
Zn	56.06
S	29.1
Trace ele	
Ag	12
As	35
Au(ppb)	5
Cd	450
Cr	50
Cu	500
Hg	78.0
Mn	5
Ni	5
Pb	
Sb	<25
Se	<25
Te	0.53
Tl	<0.2
V	<5
Zn	

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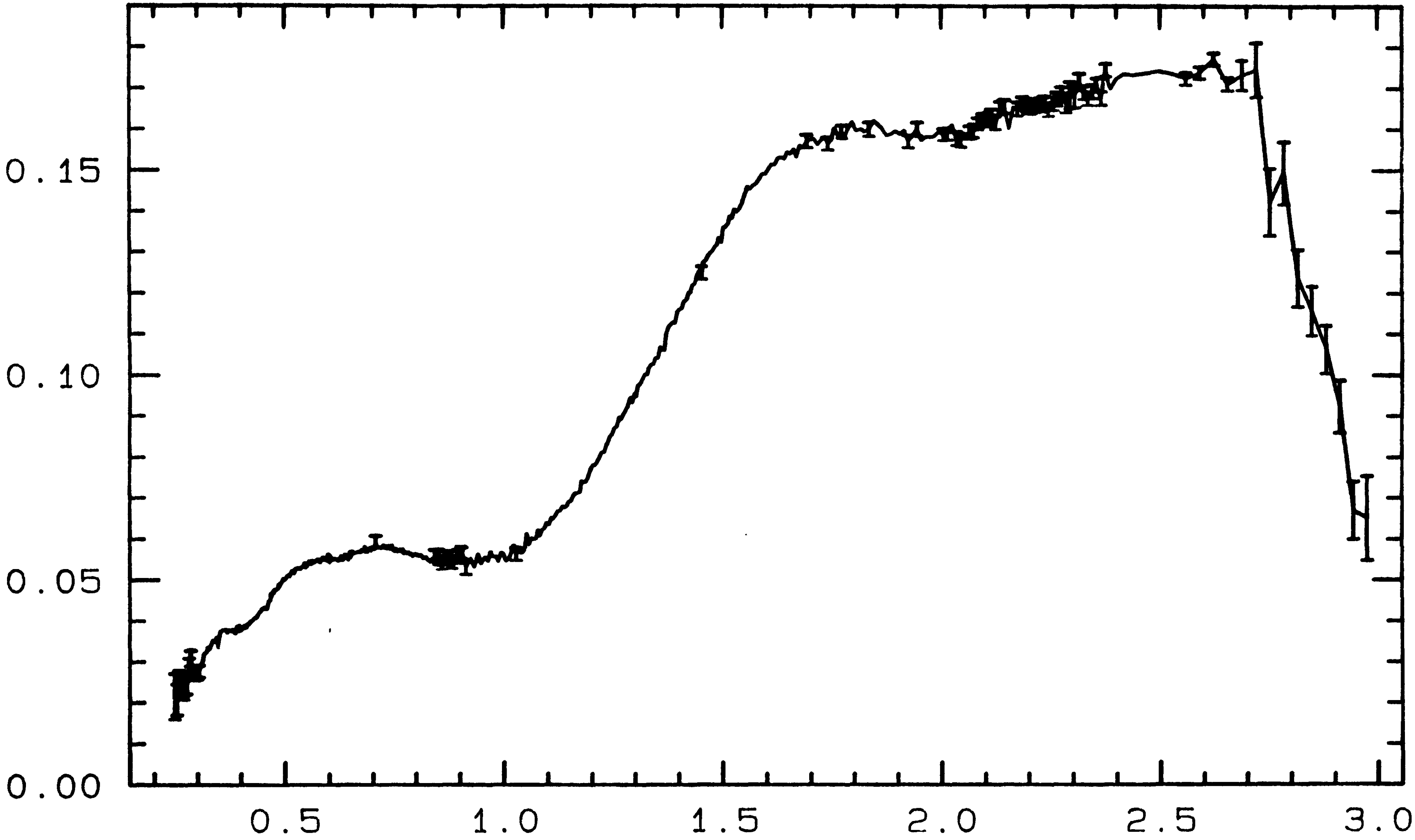
PYRITE from TYPE LOCALITY OF HIGH FALLS SHALE

Fe = 50.%
Al = 0.39%
Mg = 0.18%
Ni = 0.026%

Pb = 0.013%
* Ba = 0.015%
Co = 0.012%
Cu ≤ 0.0057%

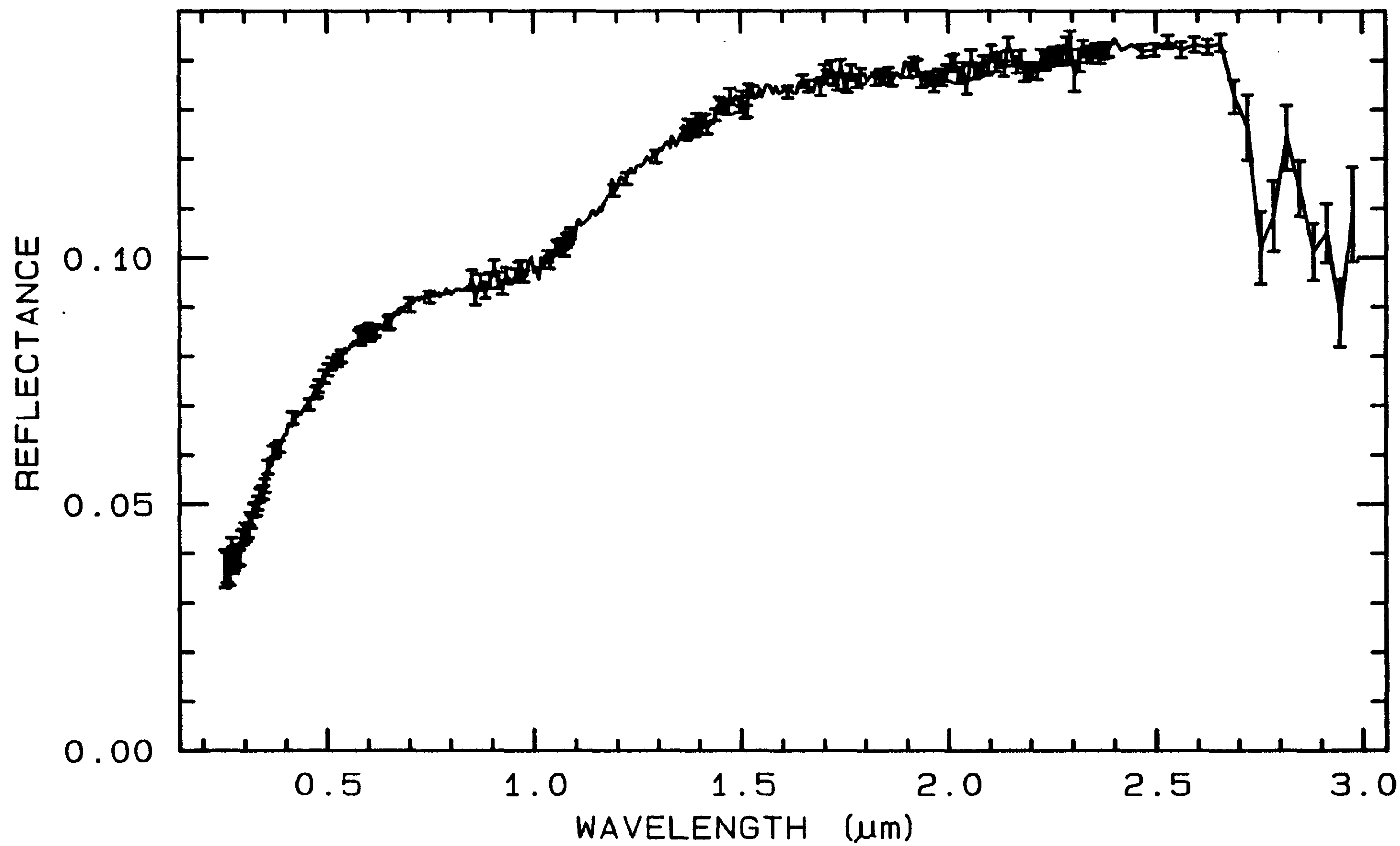
CHECK AGAINST: PYRITE
GALENA
SIEGENITE $(Co, Ni)_3 S_4$ may contain Cu or Fe
CHALCOPYRITE, ETC.
BARITE $(BaSO_4)$

Figure 22.



Pyrite S29-4 .2-3um 1x ABS REF spd023 f 495 U421p013ECg

Figure 23.



—— Pyrite S142-1 .2-3um 1x ABS REF   spd0023 f 419 Y3p013ECg

Sample	142-2?
Mineral	Py(C)
Locality	SS
Mode (wt.	
Gal	
Sph	
Cpy	
Py	55.0
Qtz	45.0
Assay (wt	
Cu	0.07
Fe	25.60
Pb	0.59
Zn	0.64
S	27.1
Trace el	
Ag	10.0
As	350
Au(ppb)	60
Cd	10
Cr	600
Cu	550
Hg	1.40
Mn	80
Ni	200
Pb	6000
Sb	<25
Se	<25
Te	0.15
Tl	15.0
V	15
Zn	7000

ınd

ıineral.

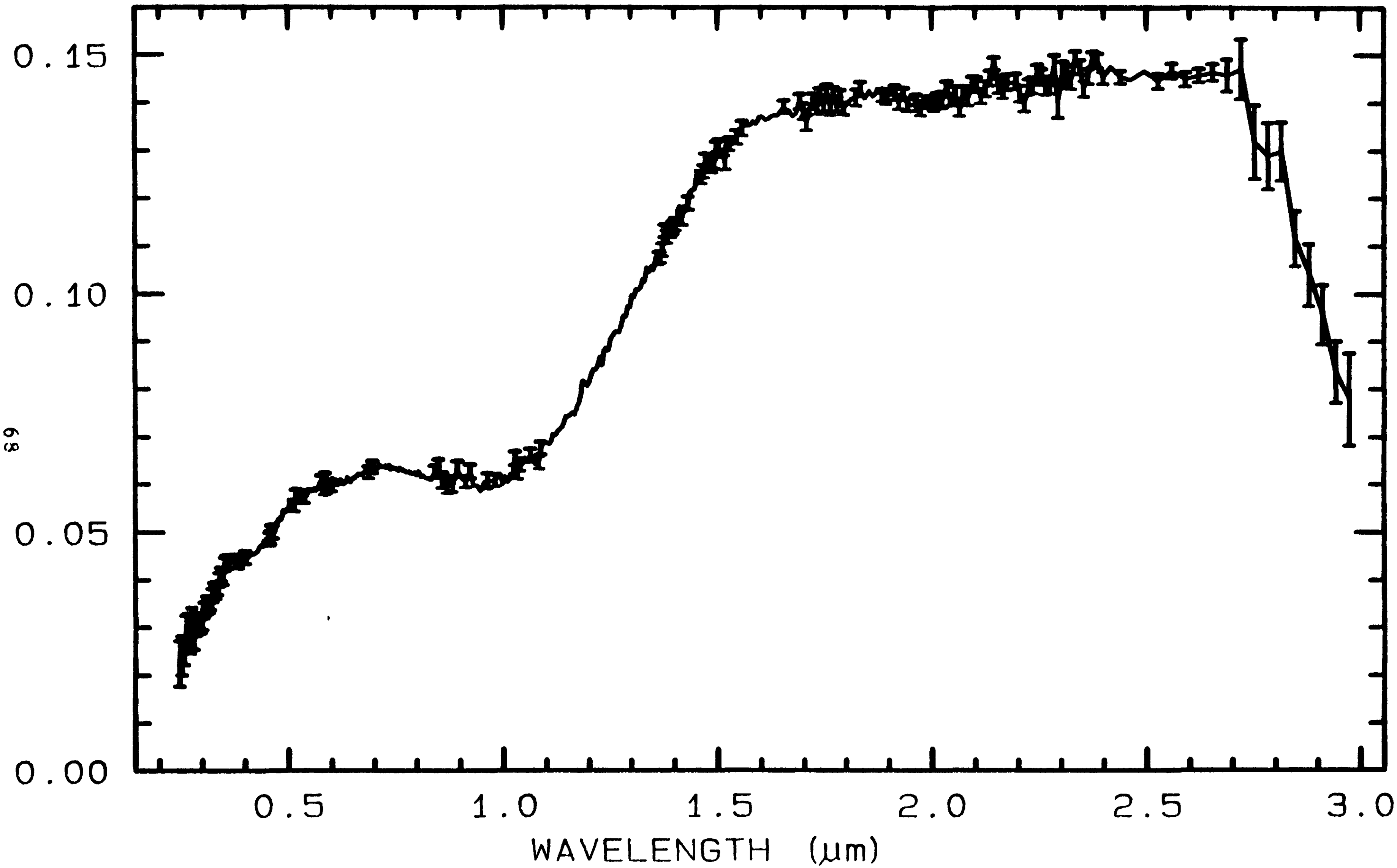
PYRITE FROM RR QUARRY, NAPANOCH

CHECK AGAINST: PYRITE group, SN minerals less likely

Fe: 47. %
Al = 0.34 %
K = 0.14 %
Cu = 0.0058 %
As = 0.11 %

Co = .0052 %
* Ti = 0.0072 %
Ni = 0.006 %

Figure 24.



Pyrite S30 .2-3um 1x ABS REF   spd023   f 467   U421p013ECg

VI. Excitation-emission-matrix fluorescence of Shawangunk-ore-district sulfides

Arnold F. Theisen

Seventeen sulfide samples (Figures 25-29 & 31-42) from the Shawangunk ore district were measured with a laboratory fluorescence spectrometer to determine their excitation-emission-matrix (EEM) fluorescence characteristics. The group of samples included eight galenas, five sphalerites, three pyrites, and one chalcopyrite. Several multiple-linear-regression (MLR) analyses were run for the samples in an attempt to correlate the observed EEM fluorescence, if any, with reported element abundances. All of the MLR analyses yielded an answer of "no unique solution".

Sphalerite samples 54-5 and 102-7 show some deep-violet emission, but there is no apparent relation to the elements reported present in measureable amounts. An EEM plot for sphalerite HS136.3B (figure 30), from the Hunt-Salisbury Branch of Geophysics USGS collection, is included as an example of potential sphalerite fluorescence. The major difference between this sample from Summit County, Colorado and the Shawangunk sphalerites measured for this study, is in the iron content. HS136.3B does not display the near-IR bands of either ferrous or ferric iron (Hunt et al., 1971) whereas these samples have iron contents that range from 3.65 to 8.2 wt% and show potential iron absorption with reflectance spectroscopy. Iron content as low as 0.1% quenches luminescence in sphalerites (Marfunin, 1979).

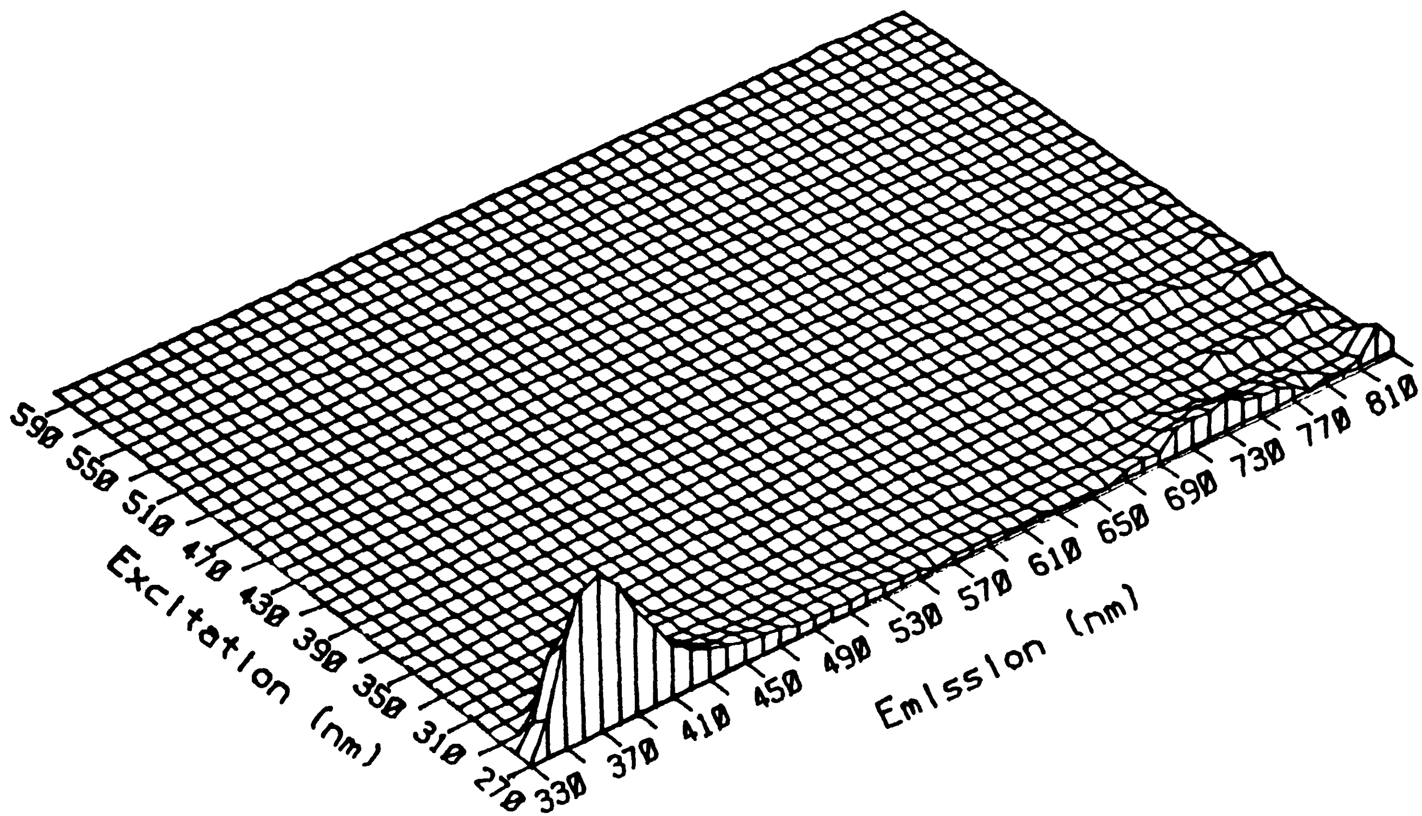
Pyrite 30-1 shows some deep-violet fluorescence, but only at high gain. Pyrite samples 29-4 and 28-8 show no measureable fluorescence.

The galena sample EEM fluorescence measurements range in category from "minor, but of no importance for remote sensing purposes", to no fluorescence whatever. In fact, a sample of galena from the Hunt-Salisbury collection was selected as a non-fluorescent, low-reflectance standard for eliminating instrument artifact noise from all EEM data sets.

The chalcopyrite sample, 26-36, EEM fluorescence reveals only noise.

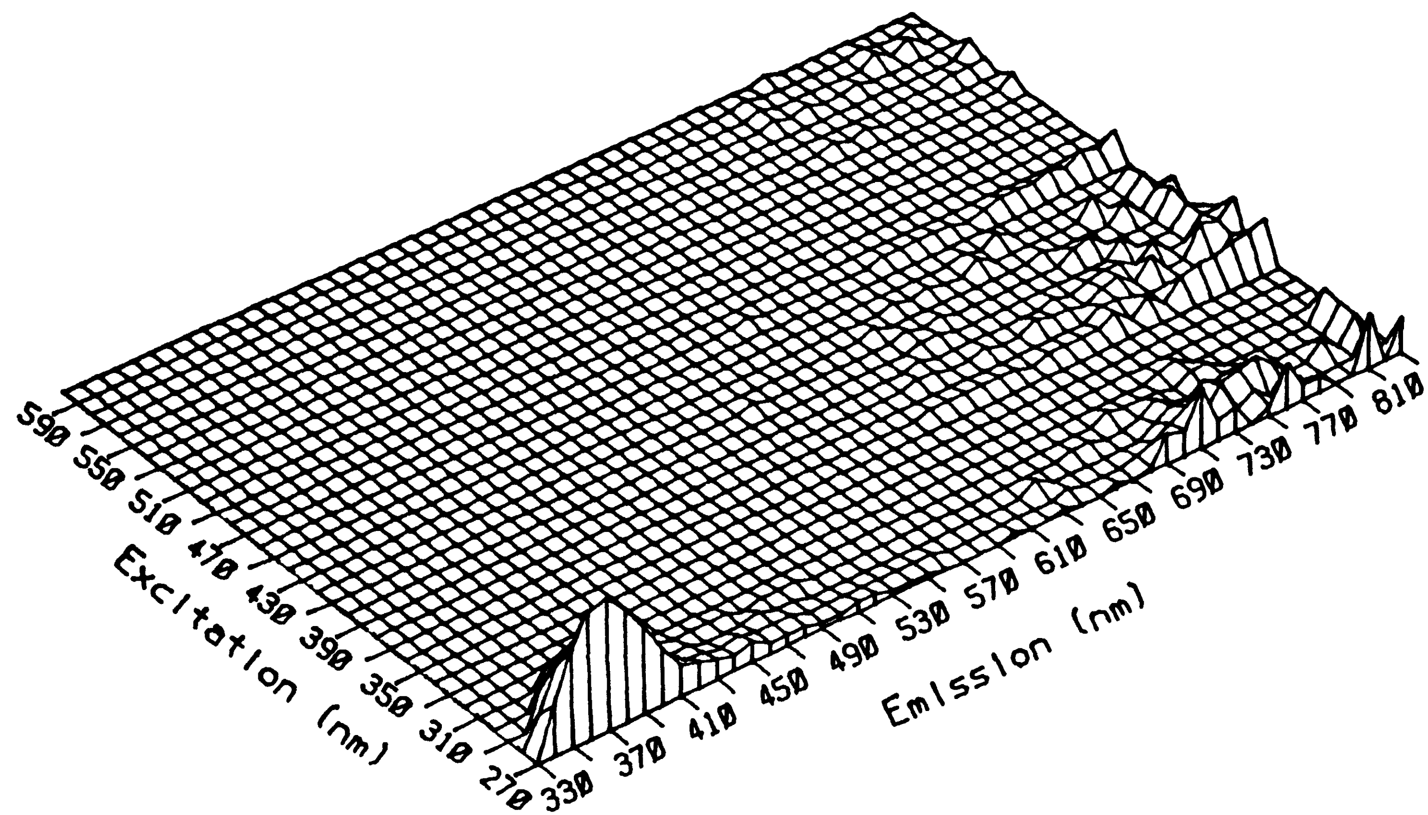
Figures 25-42. Excitation-omission-matrix fluorescence of sulfide minerals.

Figure 25.



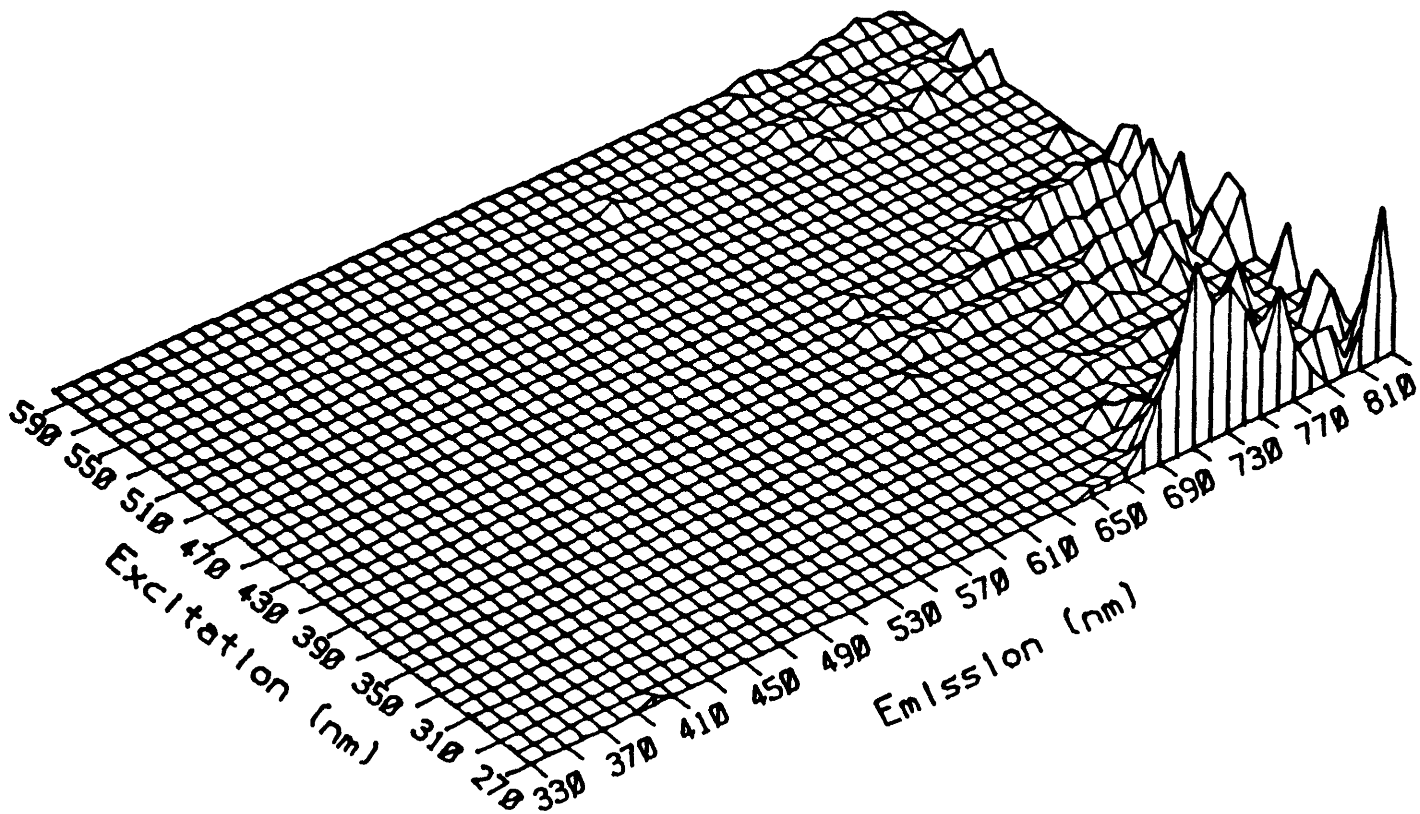
SPHALERITE JF54-5 (vs GALENA HS37.3) [A] GAIN= 1(x.671)

Figure 26.



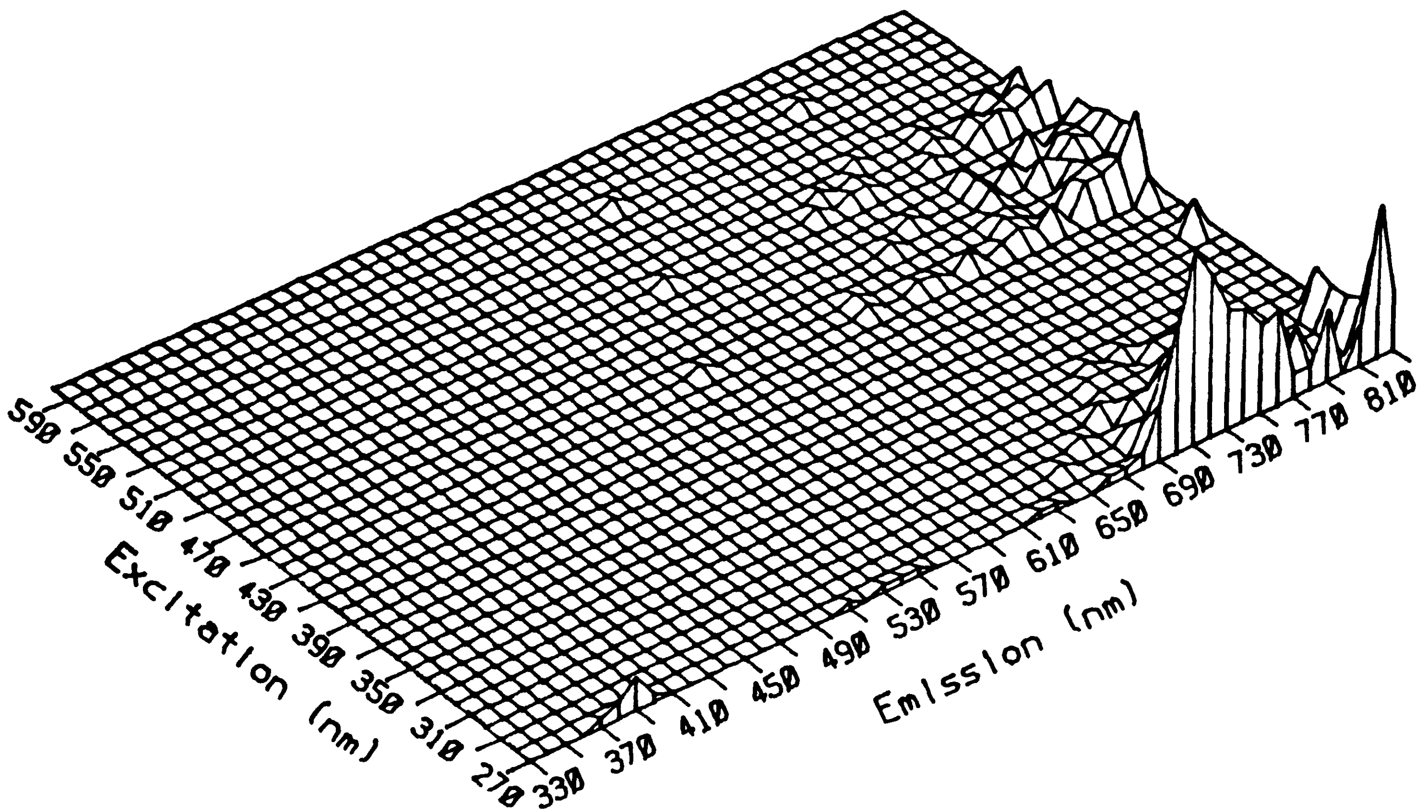
SPHALERITE JF1Ø2-7 (vs GALENA HS37.3) [A] GAIN= 1(x1.96)

Figure 27.



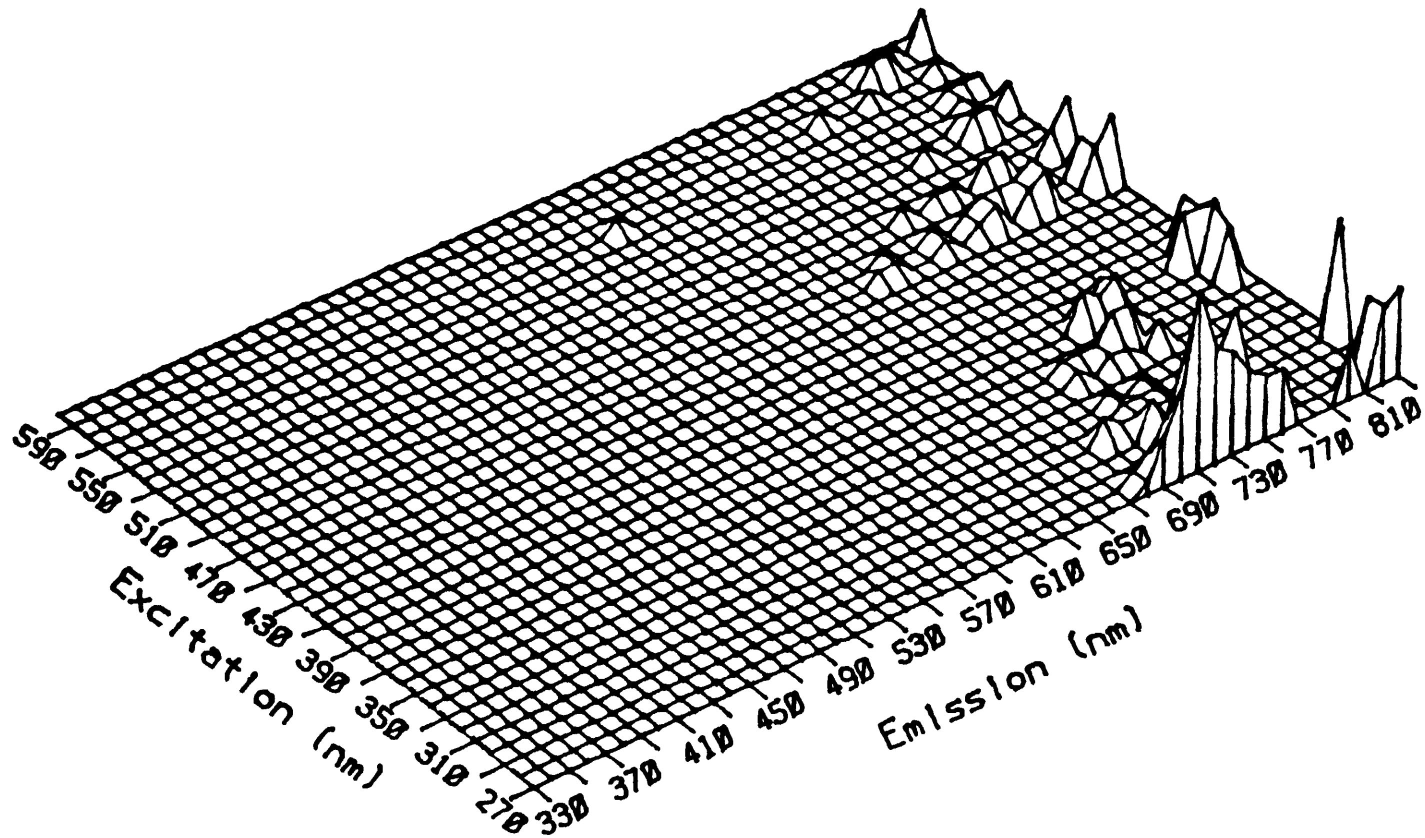
SPHALERITE JF26-34 (vs GALENA HS37.3) [C] GAIN= 1(x3.12)

Figure 28.



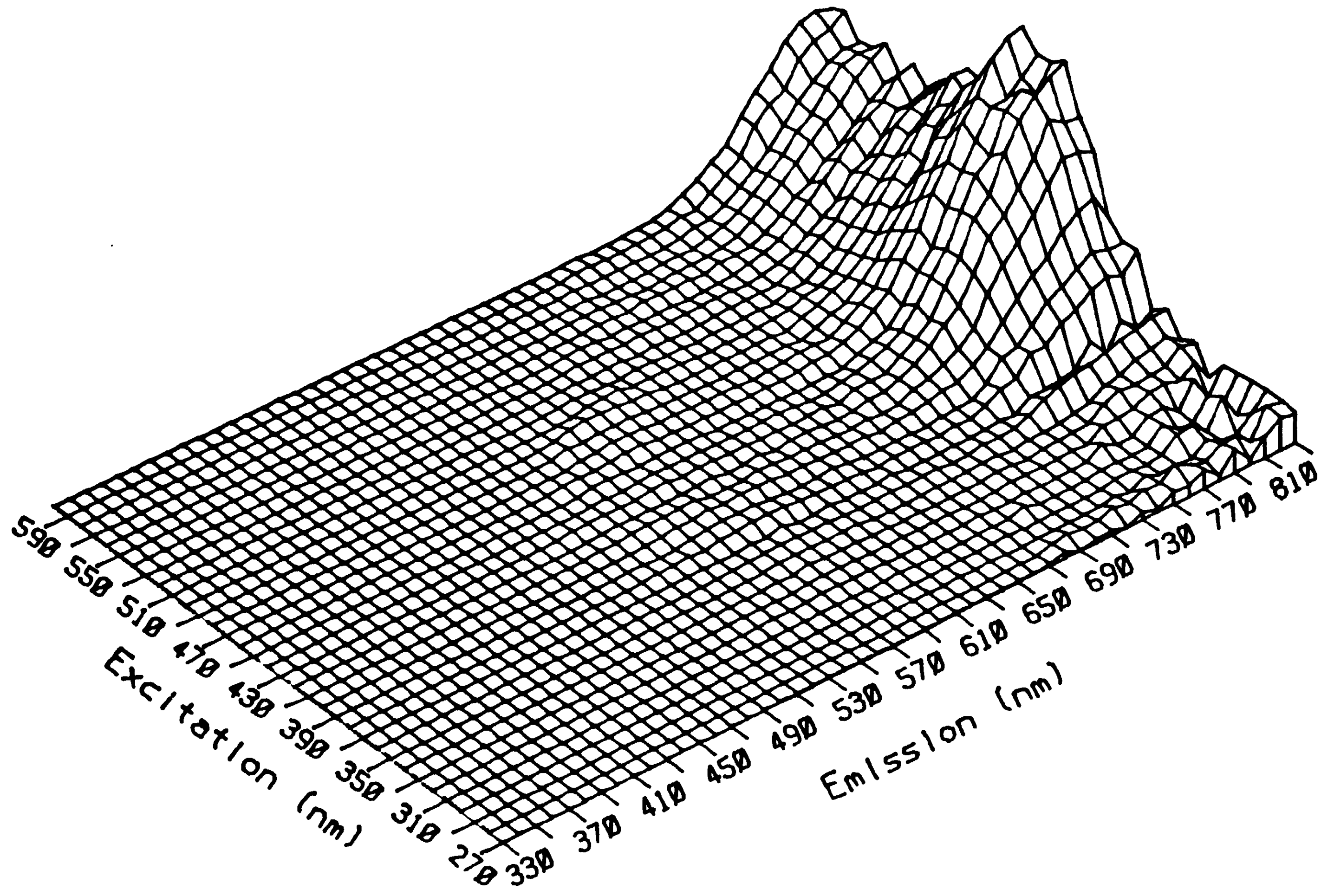
SPHALERITE JF26-35 (vs GALENA HS37.3) [C]   GAIN= 1(x3.12)

Figure 29.



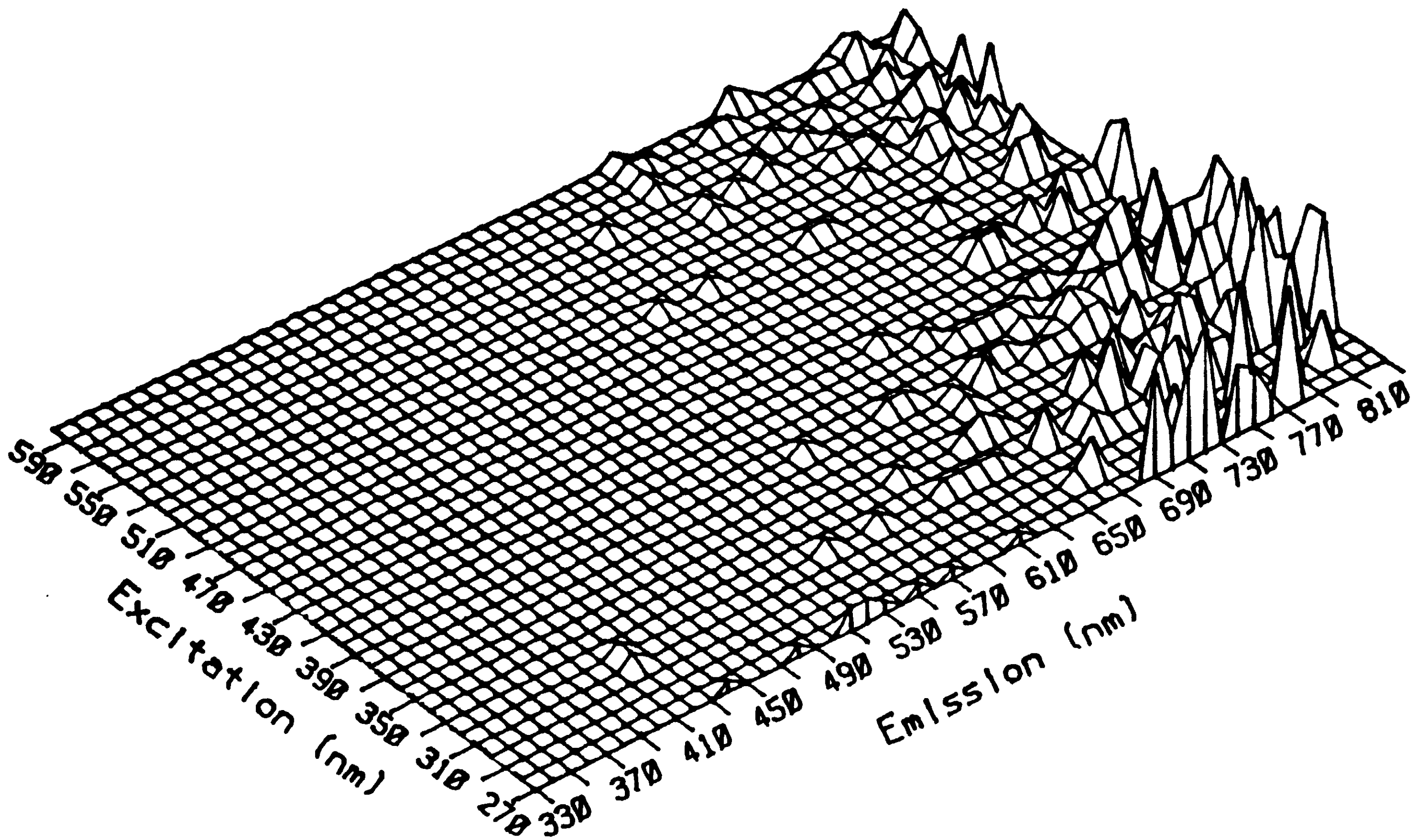
SPHALERITE JF102-8 (vs GALENA HS37.3) [C] GAIN= 1(x5.00)

Figure 30.



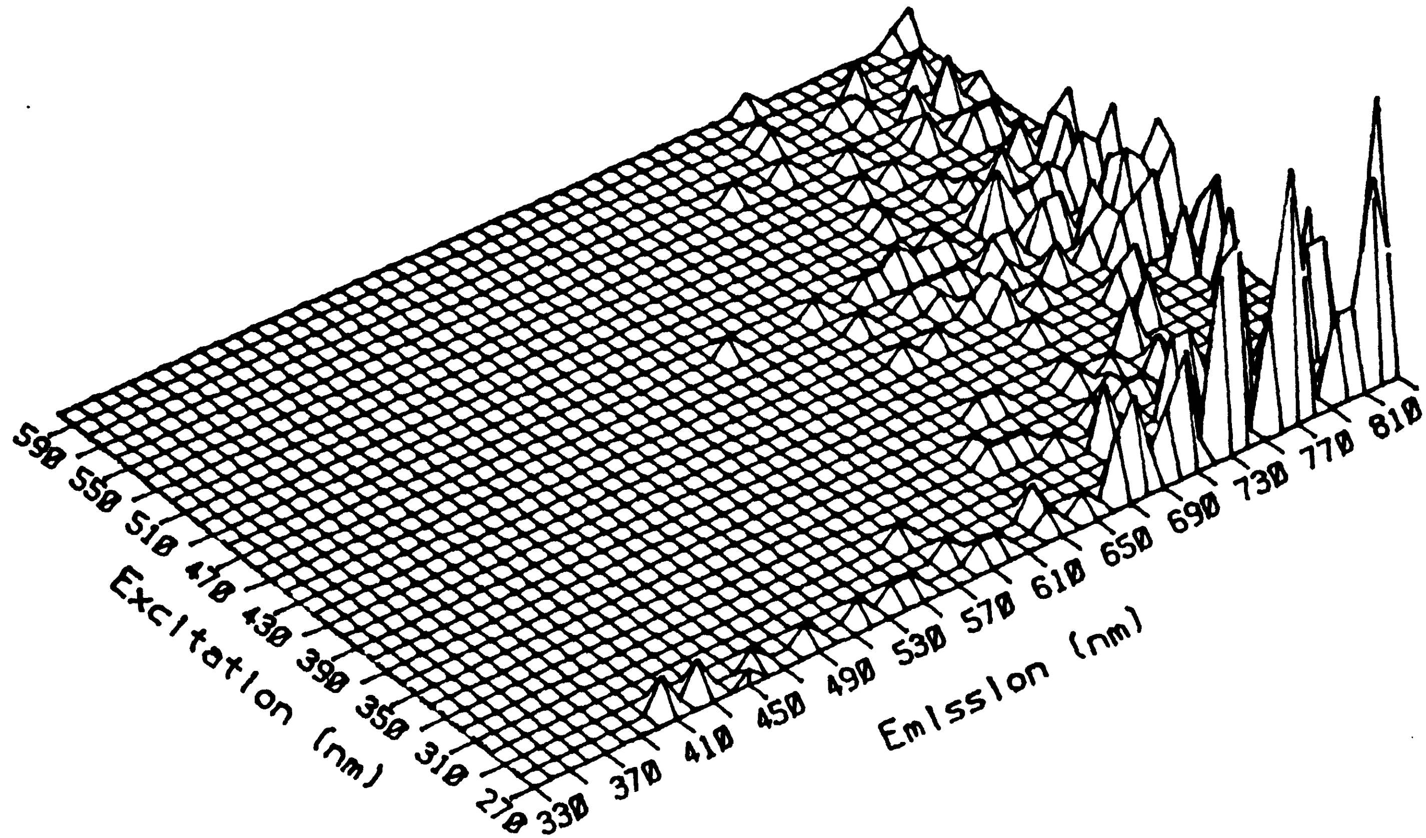
SPHALERITE HS136.3B (vs GALENA HS37.3) GAIN= 1(x.474)

Figure 31.



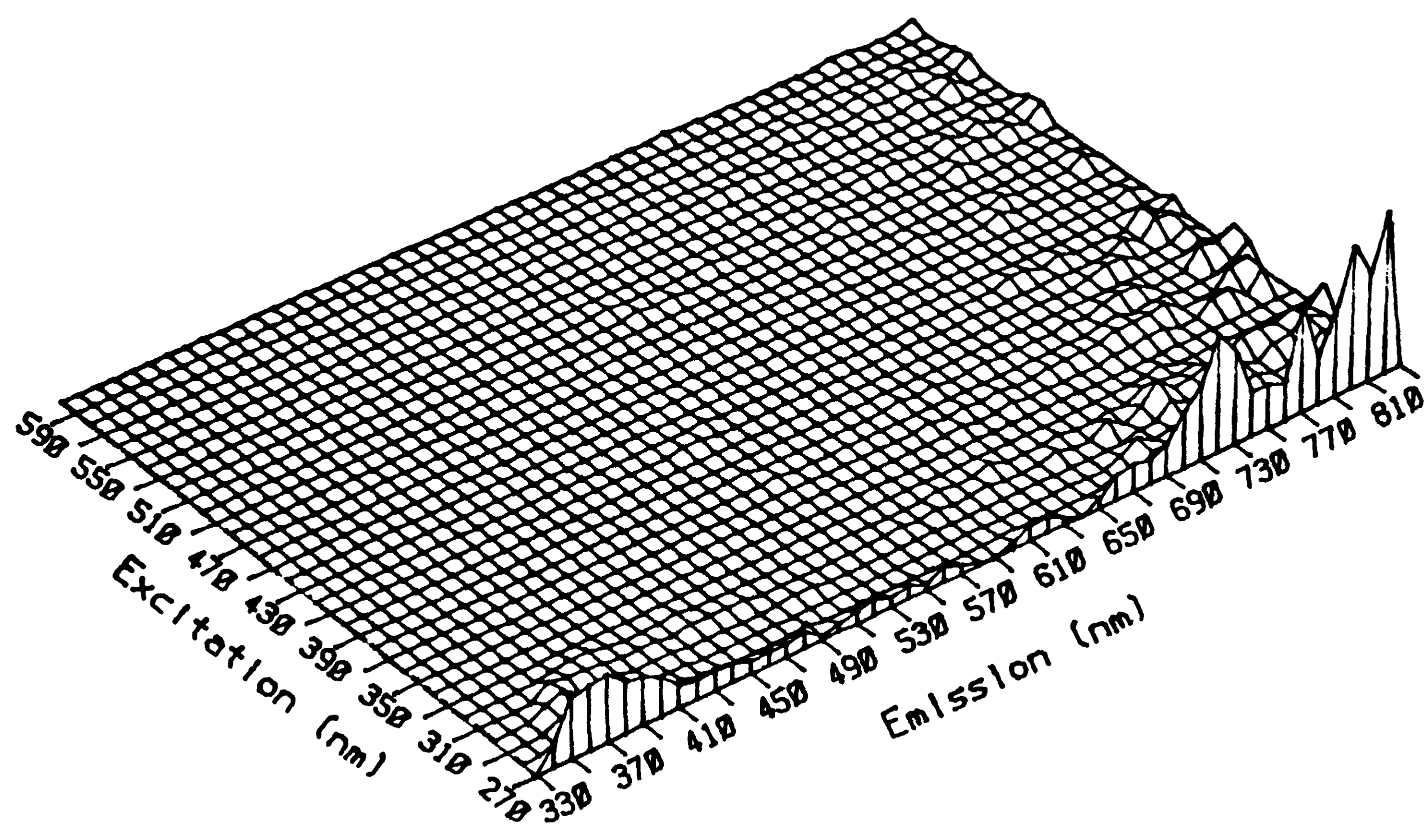
CHALCOPYRITE JF26-36 (vs GALENA HS37.3) [C]   GAIN= 3(x4.54)

Figure 32.



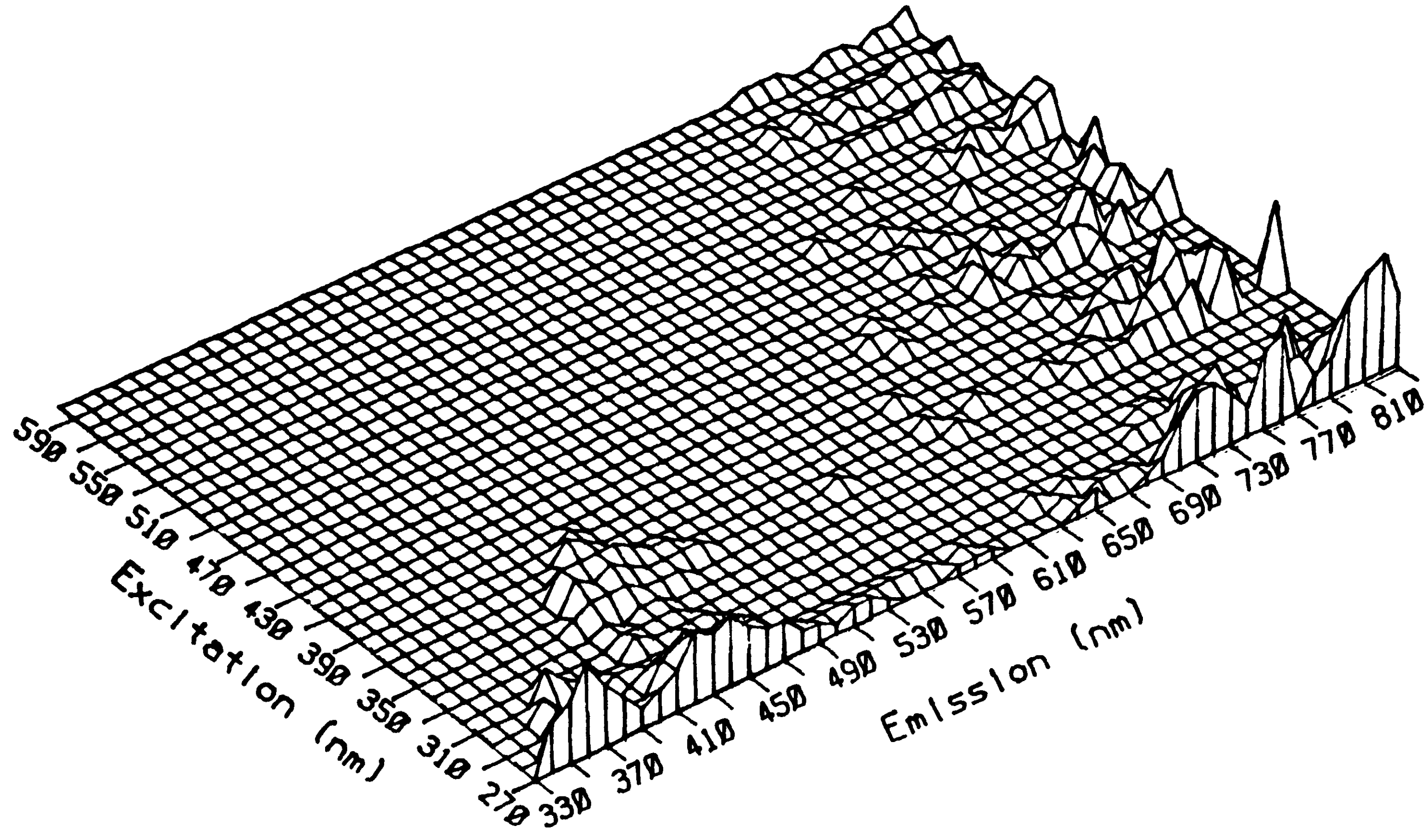
PYRITE JF26-8 (vs GALENA HS37.3) [C] GAIN= 3(x5.88)

Figure 33.



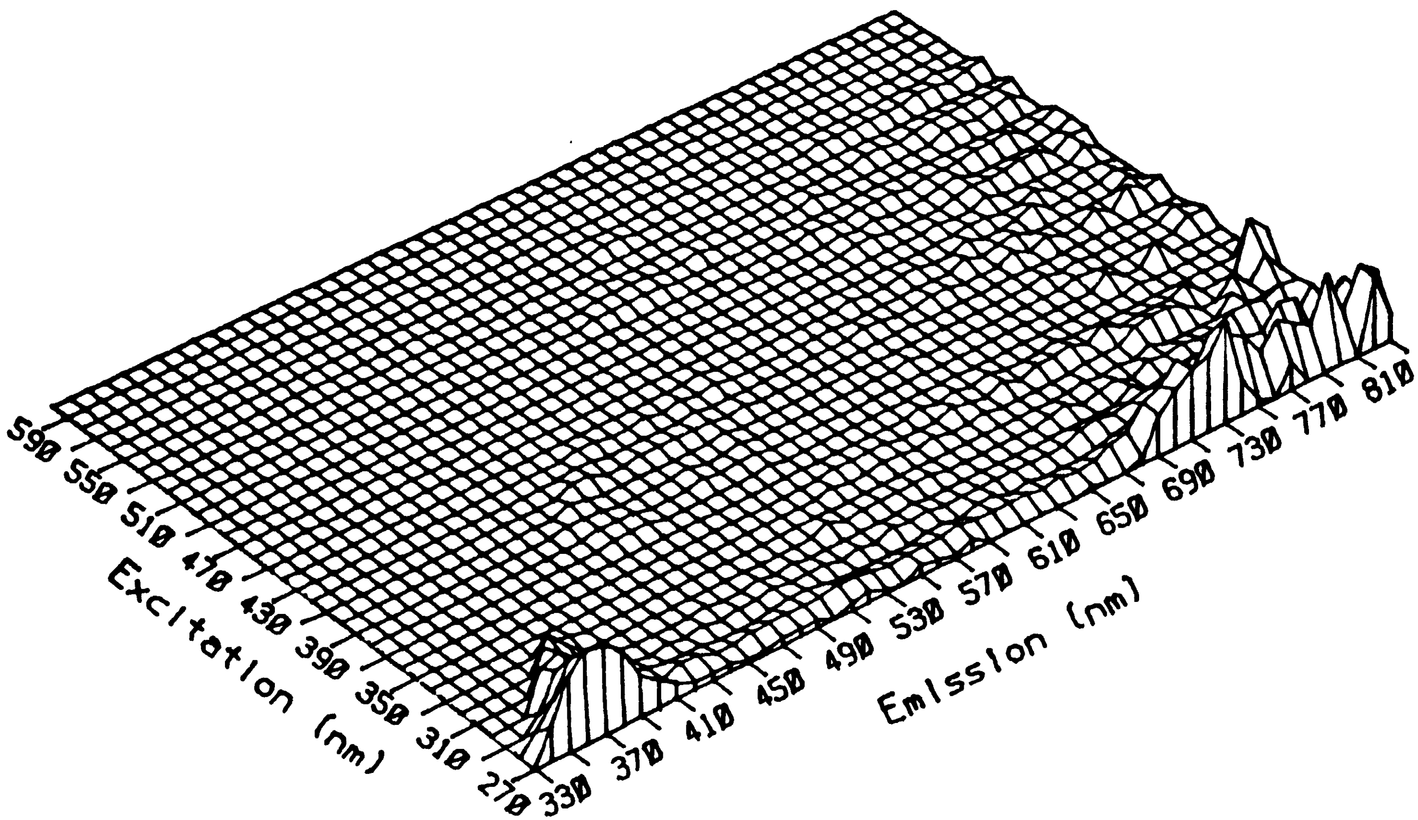
PYRITE JF29-4 (vs GALENA HS37.3) [A] GAIN= 3(x1.23)

Figure 34.



GALENA JF26-39 (vs GALENA HS37.3) [A] GAIN= 1(x3.84)

Figure 35.



PYRITE JF30-1 (vs GALENA HS37.3) [A]   GAIN= 3(x1.42)

Figure 36.

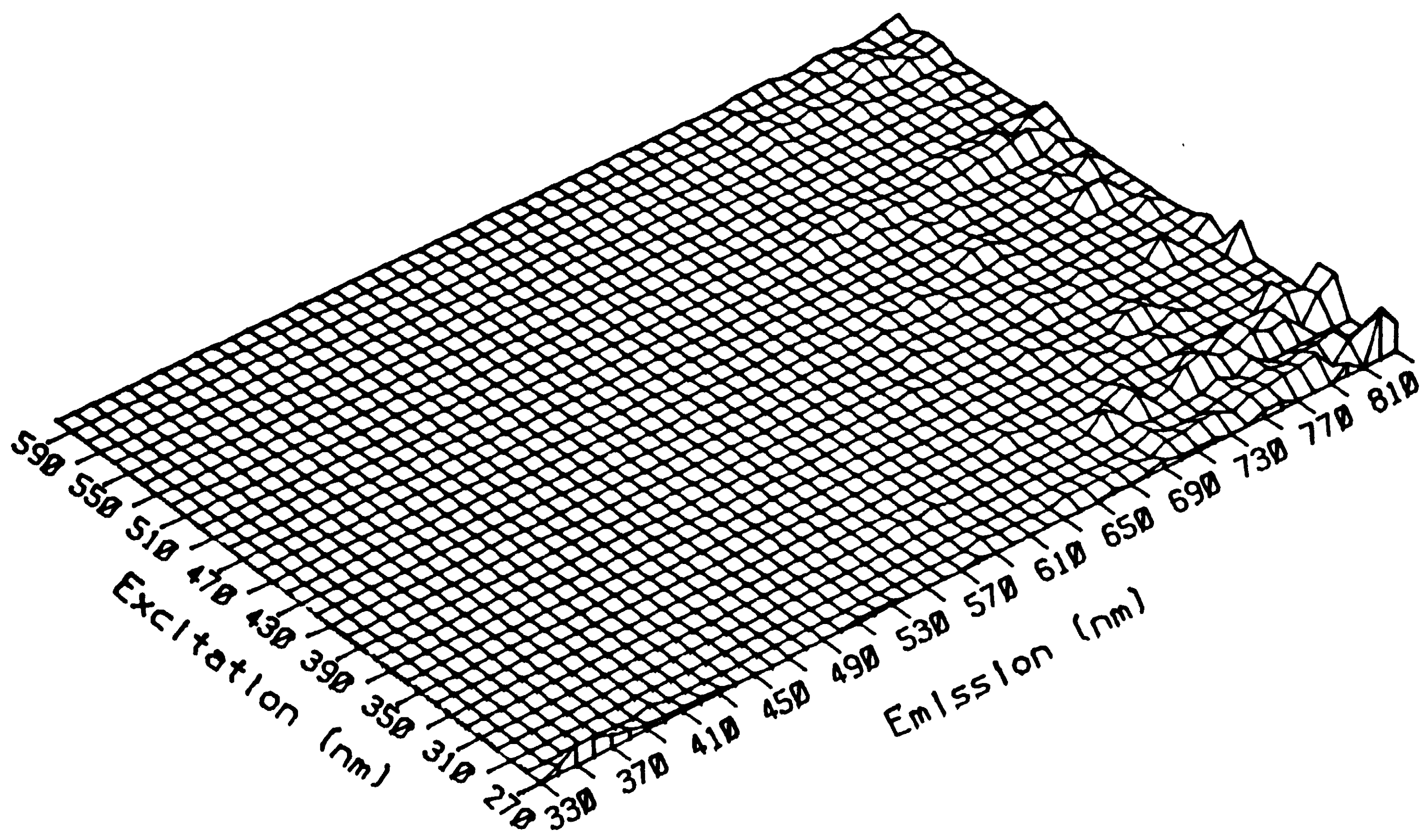
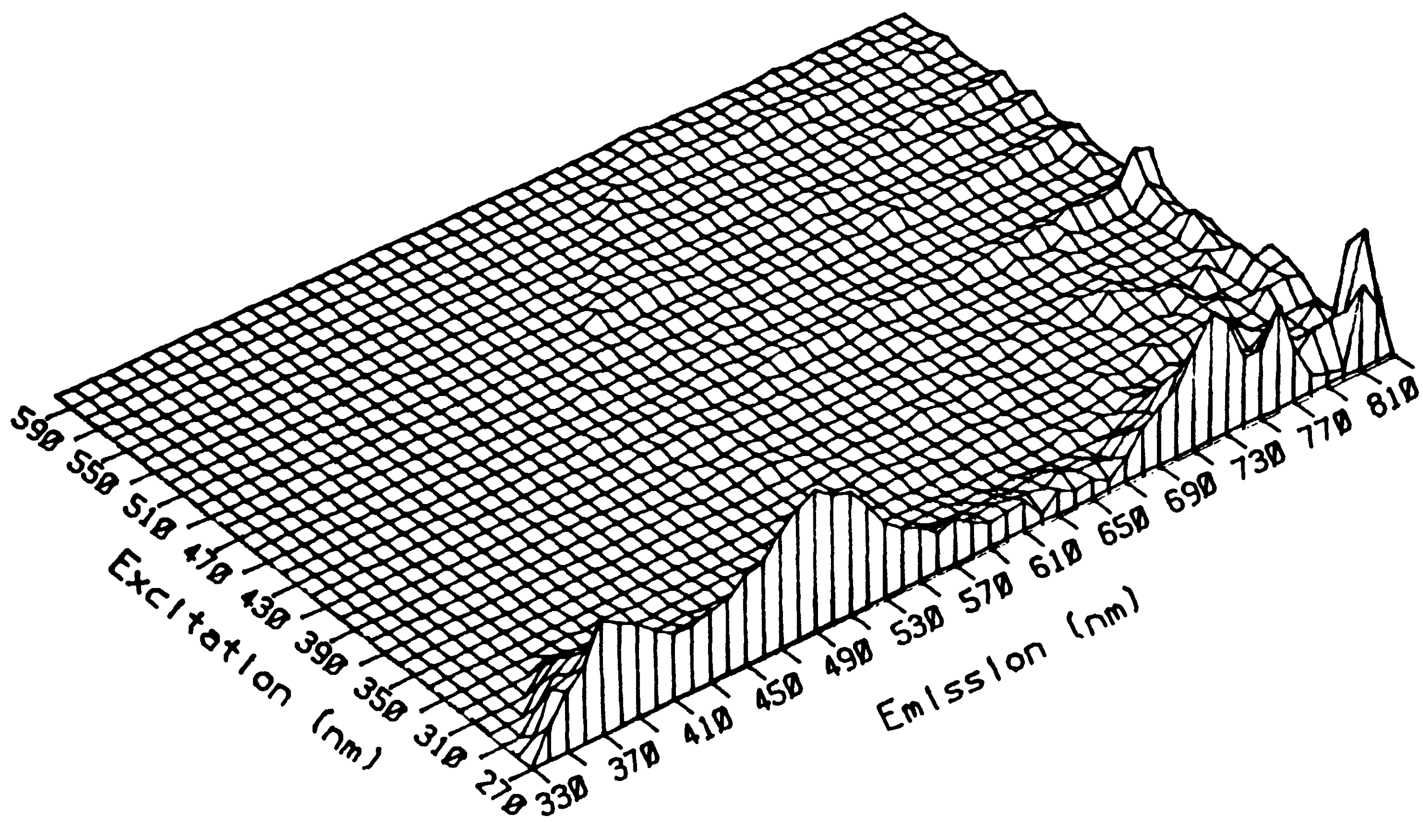
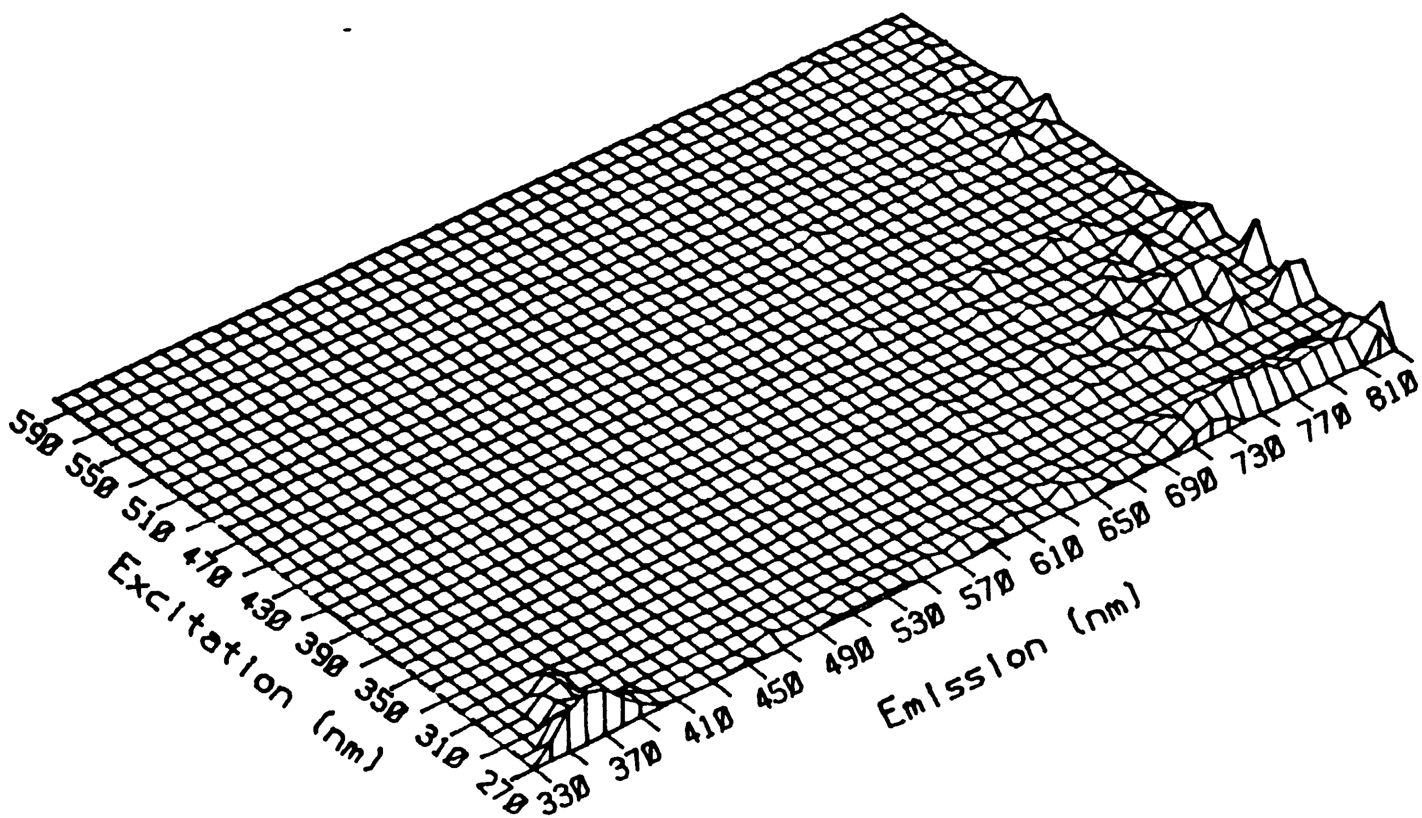

590 550 510 470 430 390 350 310 270
Excitation (nm)
330 370 410 450 490 530 570 610 650 690 730 770 810
Emission (nm)
GALENA JF26-40 (vs GALENA HS37.3) [A]
GAIN= 1(x1.56)

Figure 37.



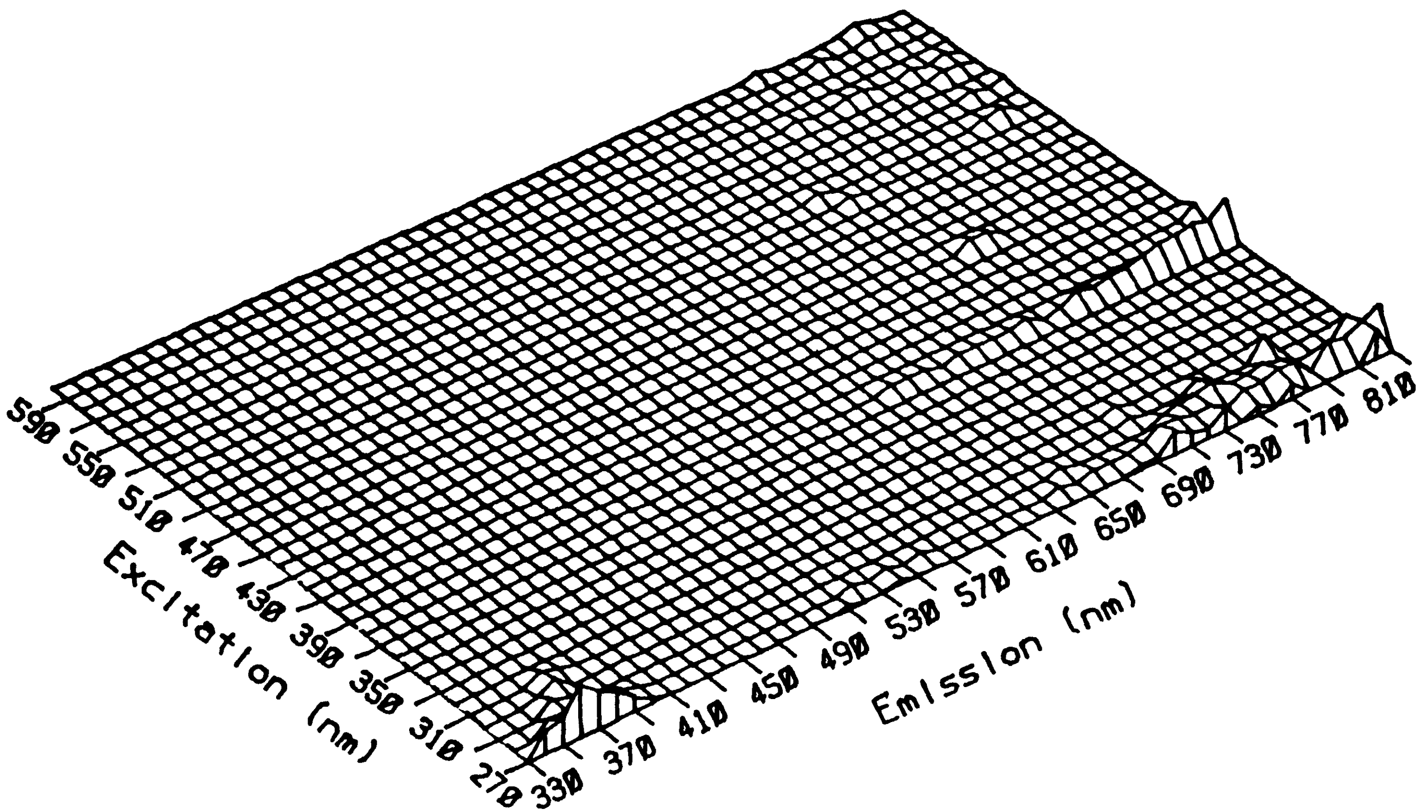
GALENA JF54-4 (vs GALENA HS37.3) [A]   GAIN= 3(x1.14)

Figure 38.



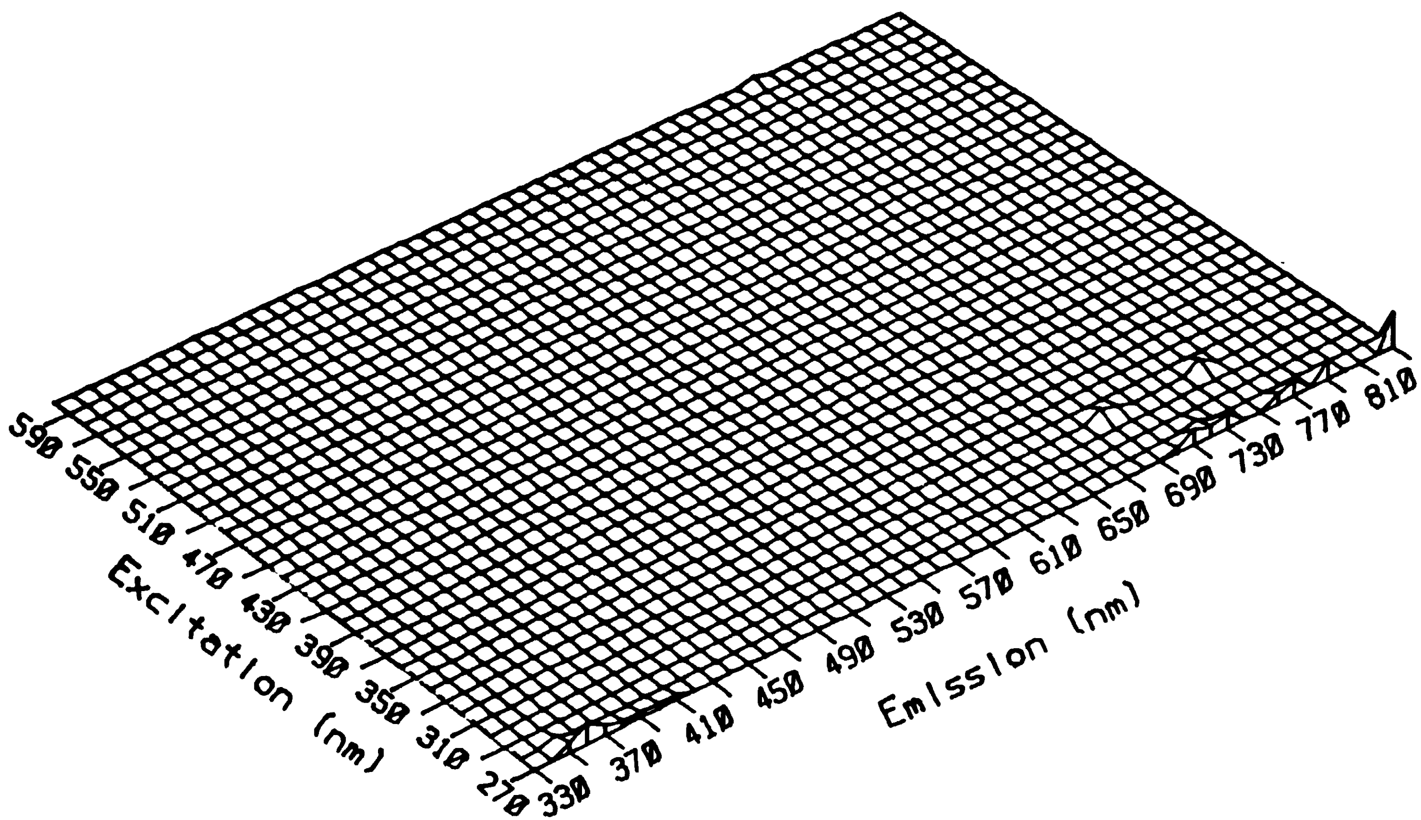
GALENA JF102-1B (vs GALENA HS37.3) [A] GAIN= 1(x1.78)

Figure 39.



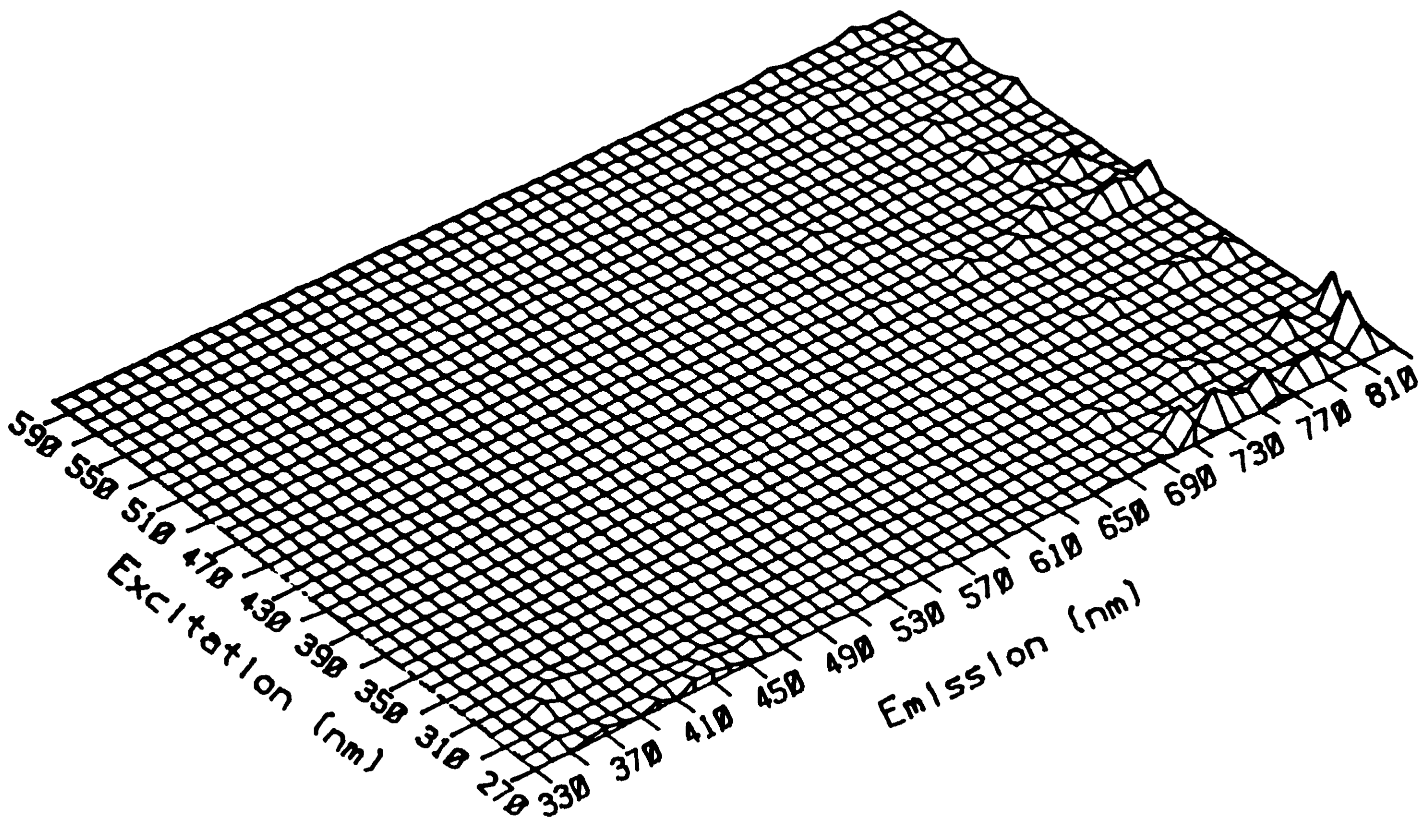
GALENA JF102-4 (vs GALENA HS37.3) [A] GAIN= 1(x1.78)

Figure 40.



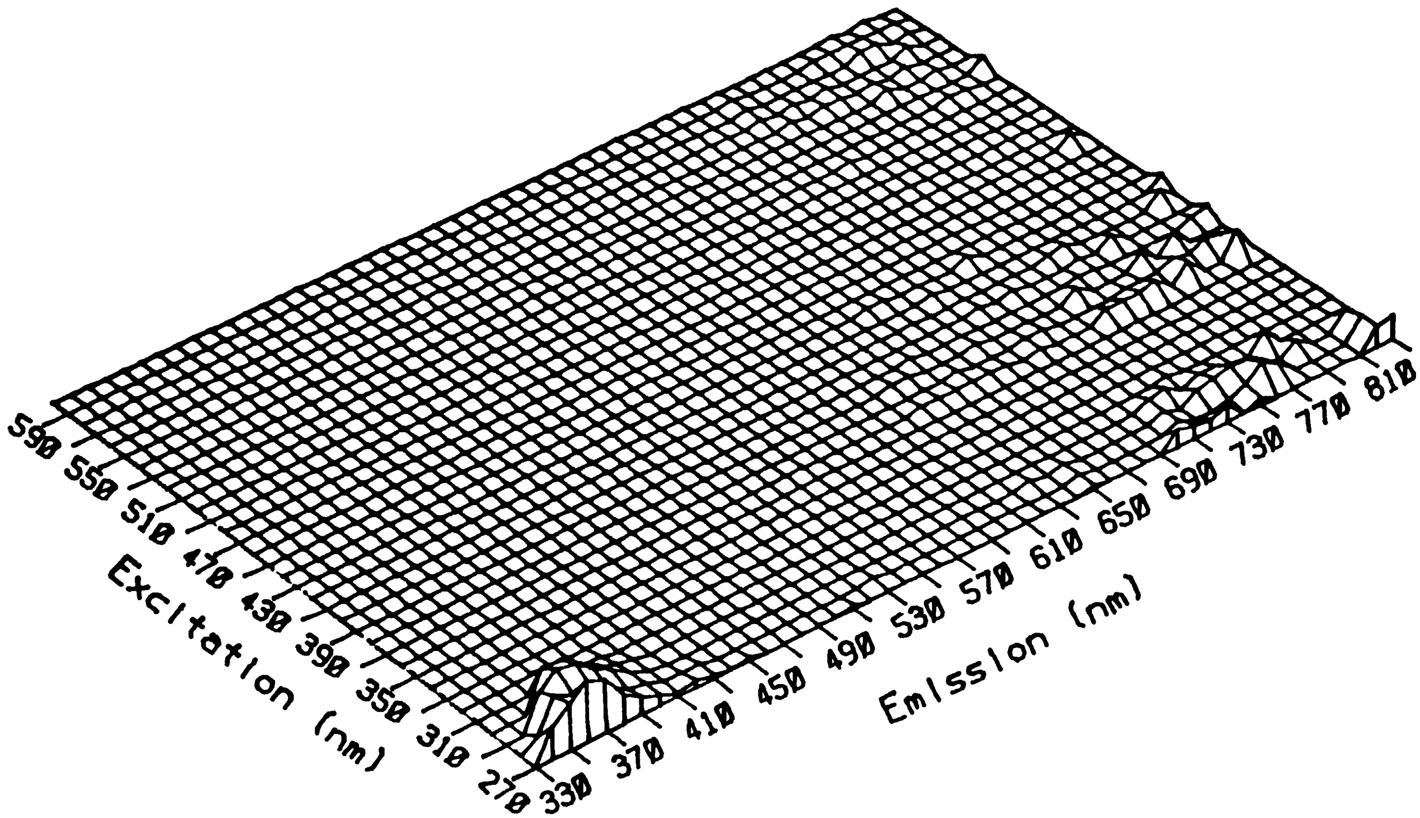
GALENA JF102-17 (vs GALENA HS37.3) [A] GAIN= 1(x1.92)

Figure 41.



GALENA JF105-2 (vs GALENA HS37.3) [A]   GAIN= 3(x1.35)

Figure 42.



GALENA JF200-1 (vs GALENA HS37.3) [A] GAIN= 1(x1.35)

Conclusions

The data sets presented in this report are best analyzed in relation to complementary data in the literature on the Shawangunk ore district, and taken together, constitute a sizable data base for genetic investigations of the epigenetic sulfide vein and open-space filling deposits of the Shawangunk ore district.

Some of the data presented here, notably the infrared spectral reflectance curves and the EEM fluorescence diagrams, represent the first such data sets available for the Shawangunk district sulfide minerals.

Preliminary interpretation of the geochemical analyses in relation to sulfide and lead isotope data reveal a relatively homogeneous ore district with slight internal trends. Sulfur $\delta^{34}S$ for sphalerite increases slightly from +25.7 per mil to +28.0 per mil to the southwest within the district, parallel to a slight decrease in radiogenic lead of galena and a decrease in iron content of sphalerite (from 8.2% at Ellenville to 3.7% at Guymard).

Ellenville sphalerite has a higher trace and major element content of Cd, Co, Fe, Hg, Sb, and probably V than the more southwesterly Shawangunk deposits. Summitville and Guymard sphalerites have higher Ag, Ba, Cr, Ti and slightly higher Mn, and Summitville may have higher Li and Ni. The highest Ag content (700 ppm) was found in Ellenville chalcopyrite, however.

In relation to sulfide deposits of the North American craton, generally identified as Mississippi-Valley-Type (MVT) deposits, Shawangunk sphalerites have generally high $\delta^{34}S$ values and galenas are low in radiogenic lead. Ellenville sphalerite is higher in Sn than MVT sphalerites, and relatively high in Hg, Sb, and Ga (but not higher than central Kentucky and Tennessee sphalerites). The Hg content is as high as 240 ppm in Ellenville sphalerite. Shawangunk sphalerites have generally higher Fe, Ti and Ag contents. MVT sphalerites have higher Cd content. The central Kentucky and central Tennessee sphalerites have much higher Ba, Hg, and Ga trace contents than comparable Shawangunk sphalerites. In MVT sphalerites, Cd:Mn ratios are decidedly higher than those of Shawangunk sphalerites (by about two orders of magnitude).

It is perhaps of genetic significance that the Shawangunk deposits are similar in lead isotope ratios and trace-element geochemistry, e.g., in Cd:Mn ratios in sphalerite, to deposits which occur at the Triassic-Jurassic border faults of the Newark Series basins and elsewhere along the Alleghanian-Variscan and post-Variscan tectonic belts of eastern North America and northern Europe. Shawangunk district sphalerites, however, have relatively high Ti and Fe contents. In this connection, the Ellenville deposit contains small quantities of the minerals brookite and rutile, which were deposited late in the paragenetic sequence.

Although surface water analyses show generally lower than average Sr content, the data suggest, but do not prove, that the Shawangunk Mountain lakes, Mohonk and Minnewaska, which are bottomed by the Martinsburg Formation have higher trace Sr content (16-36 ppb) than Lakes Maratanza and Awosting (4 ppb) which are bottomed by the Shawangunk Formation. Sr content also appears to be highest (9-46 ppb) in spring and stream waters associated with fault and fracture systems that penetrate the Shawangunk Formation down to the Taconian unconformity surface and the underlying Martinsburg Formation. Trace Zn content ranges from 21-38 ppb in those lakes bottomed by the Shawangunk Formation and waters of streams and springs associated with faults and fracture systems in the Shawangunk Formation.

References Cited

Ault, W. A., and Kulp, J. L., 1960, Sulphur isotopes and ore deposits: Economic Geology, v. 55, p. 73-100.

Bastin, E., and others, 1939, Contributions to a knowledge of the lead and zinc deposits of the Mississippi Valley region: Geological Society of America Special Paper 24, 156 p.

Brown, J. S., 1962, Ore leads and isotopes: Economic Geology, v. 57, p. 673-720.

Crawford, M. J., 1981, Geology and lead-zinc mineralization of the sandstone-hosted Shawangunk mine, New York, as compared to other lead-zinc sandstone deposits: Toronto, University of Toronto, M. Sc. thesis, 184 p.

Doe, B. R., and Zartman, R., 1979, Plumbotectonics, the Phanerozoic, <u>in</u> Barnes, H. L., ed., Geochemistry of Hydrothermal Ore Deposits: New York, John Wiley and Sons, p. 22-70.

Foley, N. K., Sinha, A. K., and Craig, J. R., 1981, Isotopic composition of lead in the Austinville-Ivanhoe Pb-Zn district, Virginia: Economic Geology, v. 76, p. 2012-2017.

Friedman, J. D., 1957, Bedrock geology of the Ellenville area, New York: New Haven, Connecticut, Yale University, Ph.D. thesis, 271 p.

Gray, Carlyle, 1953, The lead-zinc ores of the Shawangunk Mountain district: New York, Columbia University, Ph.D. thesis, 102 p.

Heyl, A. V., Delevaux, M. H., Zartman, R. E., and Brock, M. R., 1966, Isotopic study of galenas from the Upper Mississippi Valley, the Illinois-Kentucky, and some Appalachian Valley mineral districts: Economic Geology, v. 61, p. 933-961.

Hunt, G. R., Salisbury, J. W., and Lenhoff, C. J., 1971, Visible and near-infrared spectra of minerals and rocks: IV sulphides and sulphates: Modern Geology, v. 3, p. 1-14.

Jolly, J. L., and Heyl, A. V., 1968, Mercury and other trace elements in sphalerite and wallrocks from central Kentucky, Tennessee and Appalachian zinc districts: U.S. Geological Survey Bulletin 1252-F, p. F1-F29.

Klemic, Harry, Warman, J. C., and Taylor, A. R., 1963, Geology and uranium occurrences of the northern half of the Lehighton, Pennsylvania.

LeHuray, A. P., 1984, Lead- and sulfur-isotope systematics in some sulfide deposits of the Piedmont and Blue Ridge Provinces of the southern Appalachians, U.S.A.: U.S. Geological Survey Open-File Report 84-112, 429 p.

Marfunin, A. S., 1979, Spectroscopy, luminescence, and radiation centers in minerals: translated by J. V. Schiffer, Springer-Verlag Berlin Heidelberg New York, 350 p.

Nason, F. L., 1894, Economic geology of Ulster County: New York State Museum 47th Annual Report, p. 569-600.

Wilbur, J. S., 1986, Shawangunk Mountains, New York zinc-lead-copper veins--Fluid inclusion, geochemical, and isotope studies: Cheney, Washington, Eastern Washington University, M.S. thesis, 65 p.

Wilbur, J. S., Mutschler, F. E., Friedman, J. D., and Zartman, R. E., 1989, New data from zinc-lead-copper veins, Shawangunk Mountains, New York: 36 p. [in press]