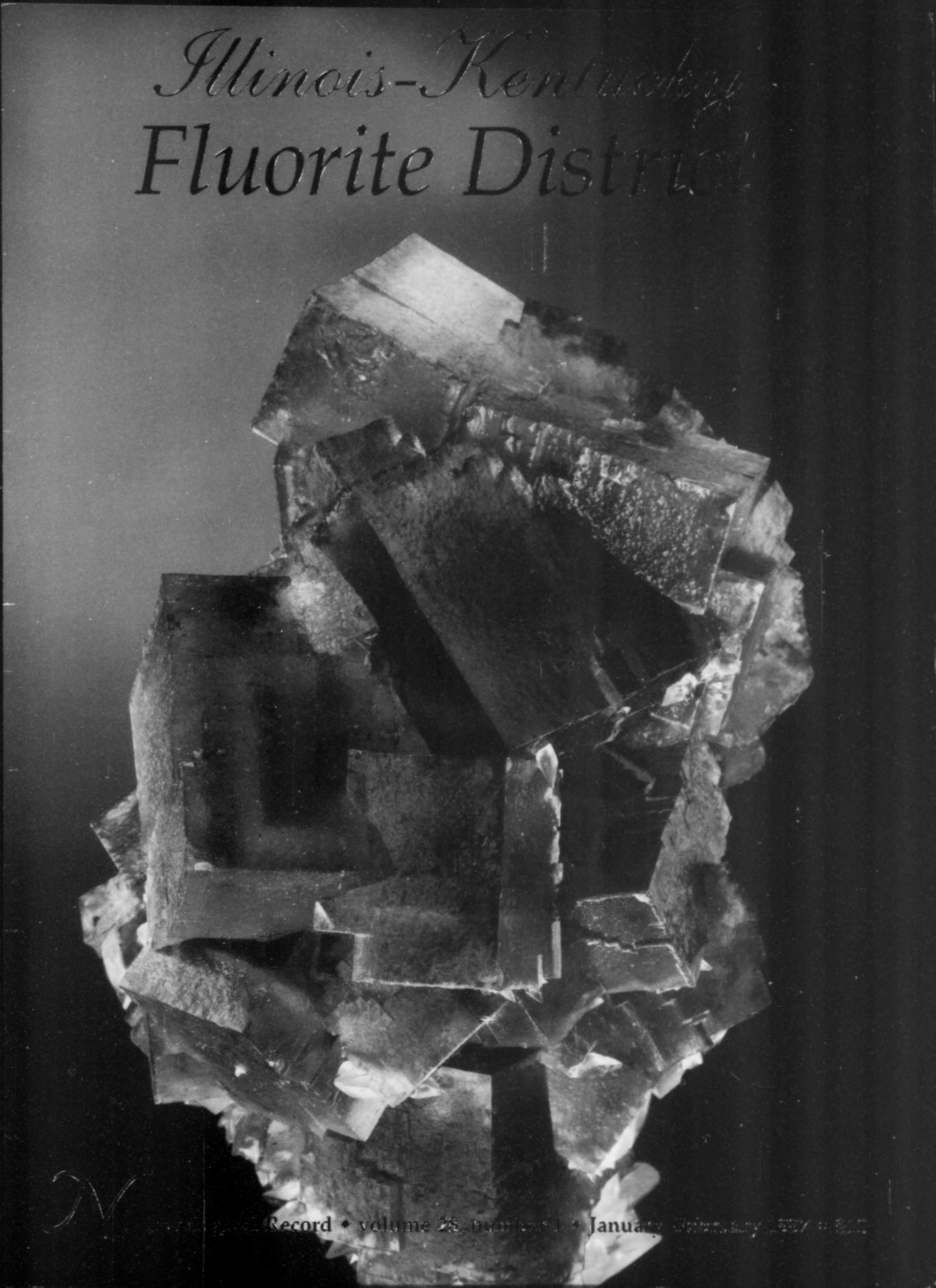
Illinois-Kentucky
Fluorite District



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*Continued on p. 79

THE MINERALOGICAL RECORD

January–February 1997 Volume Twenty-eight, Number One

The Illinois-Kentucky Fluorite District

by

Alan Goldstein

Also:

COVER: FLUORITE crystal group, 13 cm, with calcite from the Minerva No. 1 mine, near Cave in Rock, Illinois. Marvin Rausch collection; Jeff Scovil photo.

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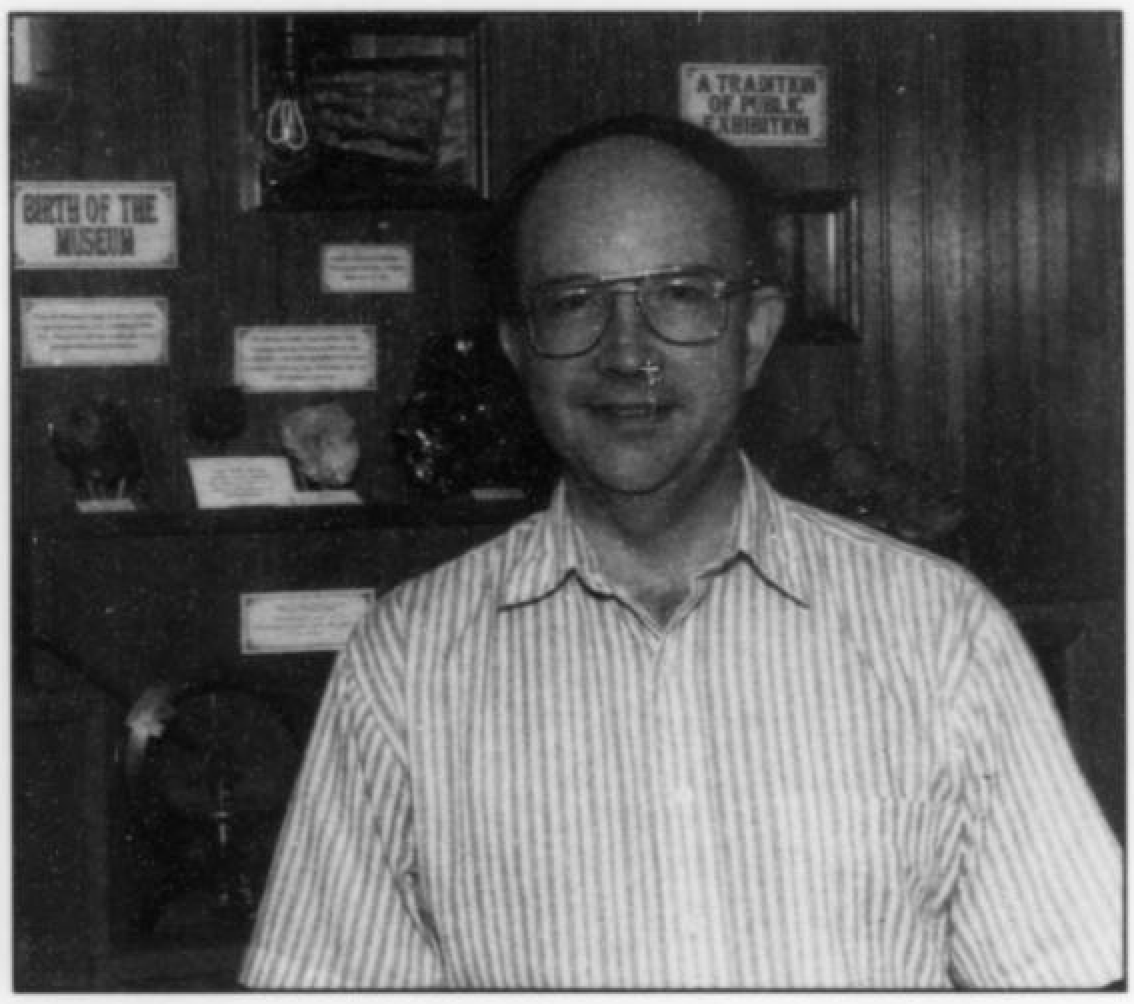
notes from the EDITOR



GEORGE ROBINSON JOINS MTU

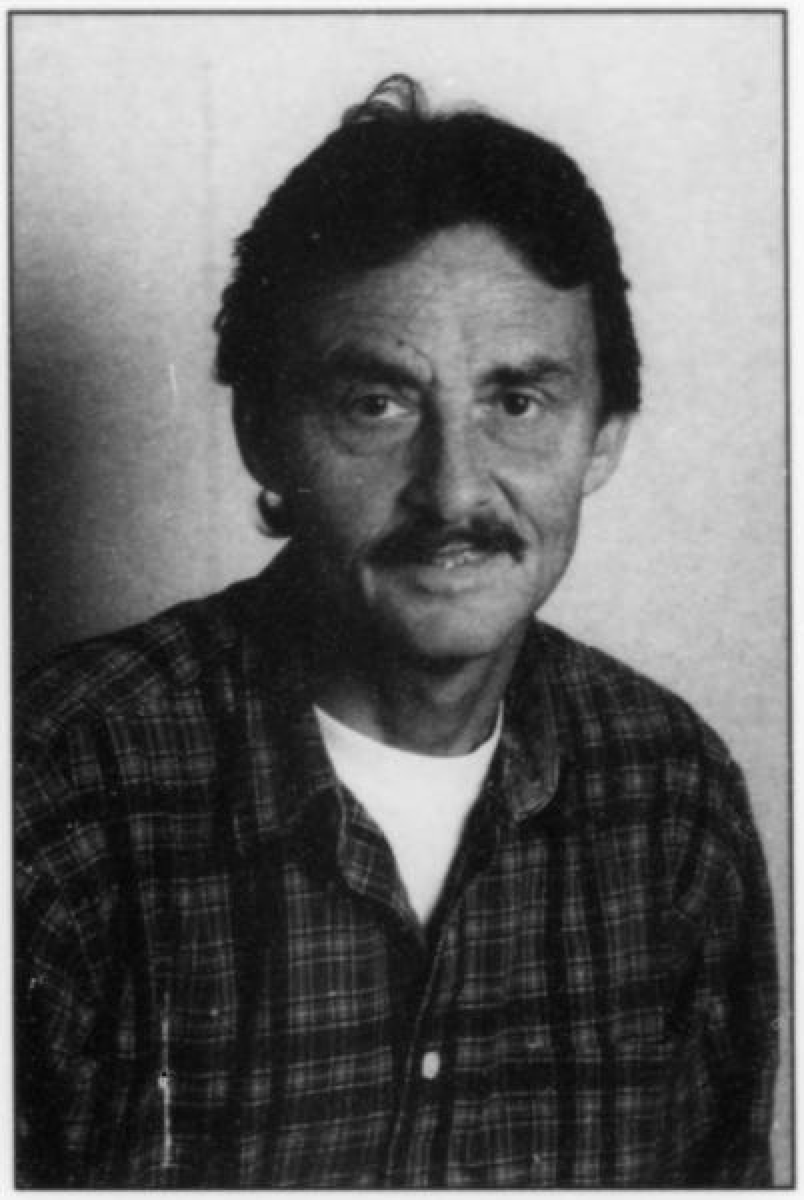
The Seaman Mineral Museum at Michigan Technological University in Houghton recently announced the appointment of Dr. George W. Robinson as Curator and as Professor in the Department of Geological Engineering. Dr. Robinson, an internationally known curator, researcher, author, educator and field collector, formerly served as Curator at the Canadian Museum of Nature in Ottawa (since 1982). He has also served as an associate editor of the *Mineralogical Record* since 1982, and as a member of the board of directors since 1985. His publications span a range of journals and subjects, but the articles he has written or co-authored for the *Mineralogical Record* include descriptions of important localities at DeKalb, New York; the Helvetia district, Arizona; Ontario's Grenville Province; the Sterling mine at Antwerp, New York; the Alpine veins near Sherbrooke, Quebec; the Nanisivik mine on Baffin Island; the fluorite mines of Madoc, Ontario; the Prenteg brookite locality in Wales; and the Yukon phosphate occurrences, not to mention his annual reviews of mineral discoveries published from 1985 to 1992. He is also author of the recently published book *Minerals*, with photographer Jeffrey A. Scovil.

Dr. Robinson will be working alongside Museum Director Stanley J. Dyl and the other museum staff, concentrating on enhancing the museum's academic role, mineralogical research, collection, displays and outreach programs.

The Seaman Mineral Museum is among the most important public mineral museums in the U.S. The collection, founded in the 1880's and named in honor of Professor Arthur Edmund Seaman (1853–1937), contains over 70,000 mineral specimens, approximately 20,000 of which are on public display. The collection is particularly rich in minerals from the Michigan copper country, including many of the finest coppers, silvers and copper-in-calcite specimens known. (For more information on the museum see vol. 23, no. 2, p. 73–76.)

CHAPMAN COLLECTION EXHIBIT

The late Albert Chapman, Australia's most prominent private collector of minerals (see the obituary in the previous issue, p. 402–403), built a fabulous collection prior to his death last year at the age of 84. The collection has found a home at the Australian Museum in Sydney, where a lavish exhibit of over 800 of his best pieces opened to the public on September 28. Additional details can be found on the museum's web site, www.austmus.gov.au. The museum is open every day from 9:30 a.m. to 5 p.m.



Christian Gobin (1943–1996)

NOTICES

Died, Christian Gobin, 53, of Venelles near Aix-en-Provence, France. Gobin was among the most prominent French mineral dealers and for many years a well-known dealer to the international community at major European bourses such as the Munich Show. Educated in Casablanca, Morocco, Gobin was exposed to the minerals of that country and soon became a collector. The cobalt mine at Bou-Azzer was among his favorite localities, where he collected wonderful specimens of erythrite and skutterudite.

In 1974 Gobin moved his base of operations to France and began dealing seriously in minerals. His efforts were very successful. Over the following 20 years he provided many world-class specimens to his customers. In the mid-1970's he brought out the first really fine azurite specimens from the now-famous mine at Touissit, and later many superb cerussites and vanadinites on white barite from Mibladen.

Gobin was very much upset in 1984 by the scandal over tinted Moroccan anglesite (locals had been chemically treating colorless specimens to turn them a rich amber color). Consequently he turned his attention to Zaïre, bringing back some of the most beautiful specimens of malachite, cuprite, cobaltoan calcite and cuprosklodowskite ever seen. More recently Gobin began traveling to China for specimens and, with his usual commitment to professionalism, began learning the Chinese language to facilitate negotiations. He brought back many fine scheelite and cassiterite specimens. These, combined with the wealth of fine specimens recovered and preserved through his efforts in other countries, rank him as an important force for mineral preservation and distribution in the last decades of the 20th century.

Eric Asselborn

The Illinois-Kentucky Fluorite District

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The Illinois-Kentucky fluorite district has been famous for fluorite and associated minerals since the early 1800's. Over 200 mines in the area have yielded a total specimen production probably numbering in the millions. With the recent closing of the last mine, the flow of beautiful minerals from this amazing district has finally come to an end, but specimens today grace almost every important museum and major private collection in the world.

INTRODUCTION

Most mineral collectors have, at one time or another, owned at least one specimen of fluorite labeled "Cave in Rock, Illinois." Although sometimes used as a generic name for any of the occurrences, "Cave in Rock" is really just a small (but important) part of the district. The many individual mines, over 200 in number, all have their histories and their particular geological backgrounds.

The Illinois-Kentucky fluorite[1] district is one of those rare mineralized areas that have produced countless beautiful specimens steadily over the course of several generations. Like the zeolites of India, or the calcites from the Tri-State area, people come eventually to take the apparently unending supply of specimens for granted. The price of fine specimens remained consistently modest, and the remarkable beauty of the specimens was underappreciated by many.

In 1995 the last operating mine in the district came to a close, ending over 175 years of specimen production in the district. The best of the specimens saved during that period are true mineralogical classics, gracing almost every important museum collection in the world, and also a huge number of private collections. To commemorate the ending of an important era in mineralogy and mineral collecting, it is appropriate to take a look back at the long history of this remarkable mining district, and to review its individual mines, their geology and their mineralogy.

[1] Historically the region has been most commonly referred to as the Illinois-Kentucky fluor*spar* district, "fluorspar" being the old miners' term for fluorite ore.

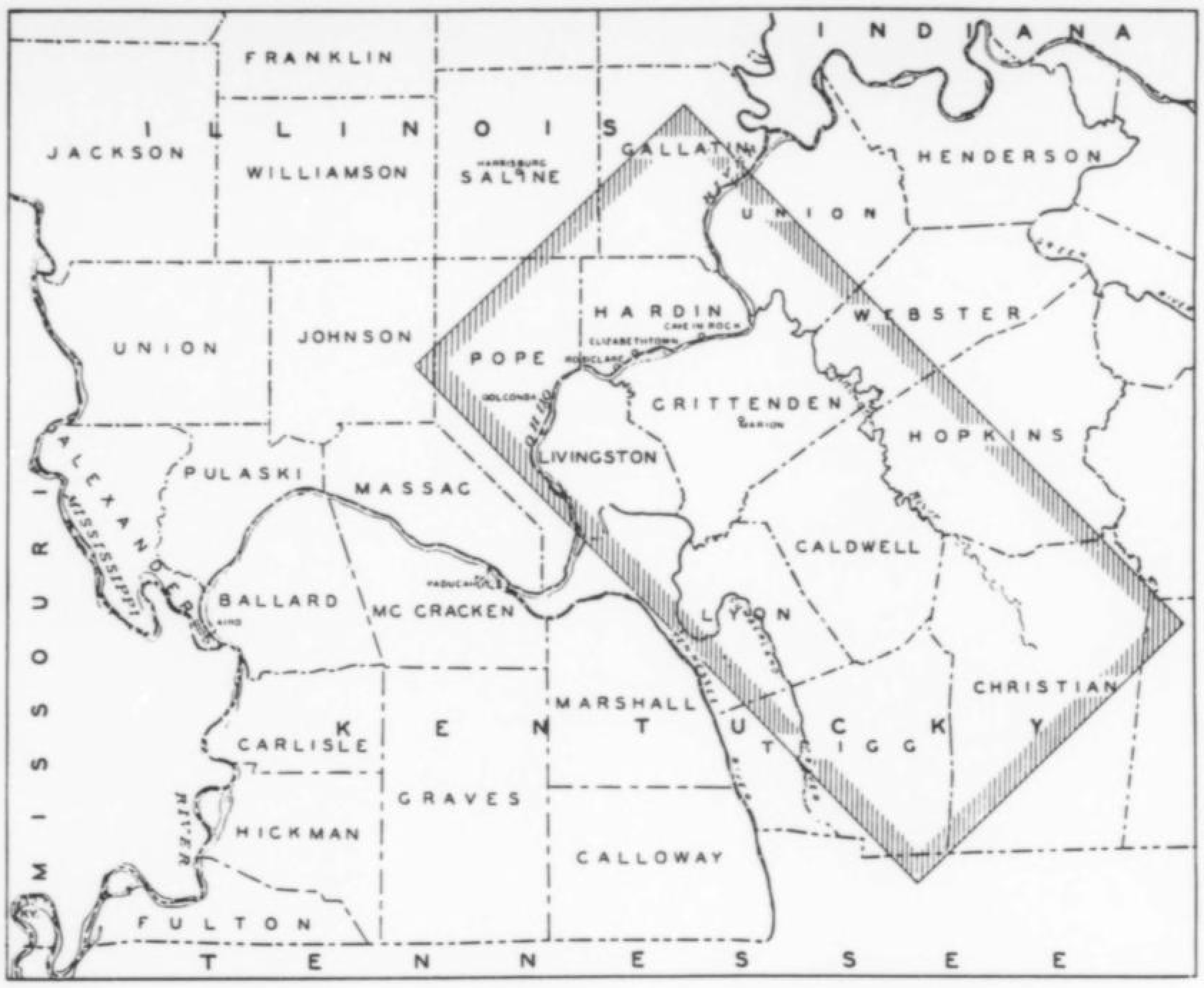


Figure 1. **Index map showing the location of the Kentucky-Illinois fluorspar district.**

HISTORY

Prehistoric Indians were aware of the occurrence of fluorite in the area prior to the arrival of European explorers. Its bright colors and softness made it suitable for carving into ornaments; fluorite artifacts today are highly sought after by archeological collectors. Indians most likely found the bulk of their fluorite lying loose on the surface, so mining was unnecessary.

Ores (galena and fluorite) were recognized in the district by settlers as early as 1812 (Ulrich and Smith, 1905). In 1819, Henry R. Schoolcraft (1793–1864) reported mineral deposits ("fluate of lime") at a place three miles back of Cave in Rock, and 15 miles below Shawneetown, Illinois. Parker Cleaveland (1780–1858), in his second edition of *Elementary Treatise on Mineralogy and Geology* (1822), reported as follows:

> Fluate of Lime . . . In *Illinois*, Gallatin County, on Peter's Creek, 17 miles from Shawneetown, and at the three Forks of Grand Pierre Creek, 27 miles from Shawneetown, and is also found occasionally on the soil for 30 miles S.W. from Cave in Rock on the Ohio [River]. It occurs massive, and in cubes, either perfect or truncated, solitary or aggregated, and is associated with galena, etc. in alluvial deposits, or in stone. At Peter's Creek it is almost always in crystals, sometimes several inches in diameter, presenting very rich and beautiful colors. Though sometimes limpid, and sometimes nearly black, its more common colors are some shade of violet, purple, red, or yellow. The limpid and yellow crystals are sometimes invested with a thin violet or red coat. At the Forks on Grand Pierre Creek, it occurs on the surface of the soil in masses which are sometimes several feet in diameter; its colors are violet, rose and green.

Documented specimens of fluorite and other minerals from the district in its "pre-mining" period are very rare. The Troost mineral collection, housed at the Louisville (Kentucky) Science Center in Louisville, contains several specimens.

The earliest mines were sunk to recover the silver in galena (although the amount of silver is very low). The first mines were opened in 1835. President Andrew Jackson was a part owner of the Columbia mine near Marion, Kentucky. The Columbia mine's main shaft is within 100 yards of the original shaft. The Royal mine (also known as the Royal Silver) was opened near Smithland, Kentucky, at about the same time (Ulrich and Smith, 1905).

The first occurrence of lead in Illinois (other than Peter's Creek) was found while sinking a well on the farm of Mr. James Anderson in 1839. Two years later, a second well sunk nearby encountered additional ore. This was to become an important orebody over the next century.

In 1842, Mr. William Pell discovered fluorite and galena on his farm about one-half mile northwest of Rosiclare, Illinois. He started the first Illinois mine, which operated for the next eight years. The Rosiclare mining district was the center of activity during the mid-1800's (Bastin, 1931). At that time, the Cave in Rock area was not being actively mined.

In the early history of the district, virtually all mining was for galena. Fluorite was considered a useless gangue mineral (Bastin, 1931). The Civil War brought increased production of lead from both Illinois and Kentucky mines; however, in the following decade, the lack of adequate transportation facilities and the depreciation in market value of lead closed most mines. Kentucky mines suffered the most, due to the distance wagons carrying ore had to travel. The Rosiclare mines, located near the Ohio River, continued to operate successfully (Ulrich and Smith, 1905).

In the 1880's, new steel-producing methods which incorporated fluorite flux were used, causing a rejuvenation of mining (Weller *et al.*, 1952).

After 1900, the mining of fluorite became more intense, and activity in the district increased. The heart of activity was in Rosiclare, with mines operated by the Fairview Fluorspar and Lead Mining Company (Weller *et al.*, 1952). Major Kentucky mines include the Hodge, Memphis and Yandell mines (Ulrich and Smith, 1905).

Figure 2. **Rosiclare Lead and Fluorspar Company storage bins, ca. 1920. Edwin Reeder photo, courtesy of Mary Hardin.**

World War I brought an unprecedented demand for fluorite and an expanded search for new orebodies. No new large deposits were found, though many small mines opened.

Disaster struck in the Illinois portion of the district in 1923 when virtually every mine along the Fairview-Rosiclare vein was flooded. A mine extension had encountered water from the Ohio River, flooding level after level. Eventually the entire mine complex was affected. Pumps removing 3,000 gallons per minute operated while equipment was salvaged from the mines. By the beginning of the following year, several adjoining mines on the adjacent Blue Diggings vein were dewatered. Mines on the Fairview-Rosiclare vein were not dewatered until 1940 (James Bradbury, personal communication). While these important mines were closed, activity shifted to the Hillside and Daisy mines and to mines in Kentucky (Weller *et al.*, 1952).

In January 1937, the Ohio River rose to the highest level ever recorded (over 54 feet above normal); virtually all mining activity was brought to a halt for eight weeks as surface buildings were damaged and roads, mines and towns were flooded. Transportation and communication were reduced to boat and shortwave radio (Weller *et al.*, 1952).

The Cave in Rock district became most important after World War I. The Spar Mountain escarpment was extensively mined along its flank from 1919 to 1939. Deeper into the escarpment, mining was carried out until the mid-1970's. The famous Crystal mine operated from 1934 to 1976 (Gill Montgomery, personal communication).

Major district mines of the past 100 years are listed in table 1 (Currier, 1923; Pinckney, 1976; Ulrich and Smith, 1905; Weller *et al.*, 1952; and G. Montgomery, personal communication).

The Illinois-Kentucky fluorite district has been, by far, the largest producer of fluorite in the United States. More than 90% of the domestic production in 1985 was from this district (G. Montgomery, personal communication). There are other districts, some associated with volcanics in the western U.S., but because they are far from centers of use and do not have the ease of transportation as does the Illinois-Kentucky district. These other fluorite sources will

Table 1. **Major Illinois and Kentucky fluorite/galena mines.**

Illinois mines	*Kentucky mines*
Annabel Lee #1, 3	Babb
Blue Diggings	Big Four
Crystal #1	Blue & Marble
Daisy	Columbia
Davis-Deardorff #1, 2	Haffaw
Denton #1, 3	Hickory Cane #2
Gaskins #1	Hodge
Good Hope-Extension	Hutson #2
Hillside	Klondike
Jefferson	Lafayette
Minerva #1, 4	Mary Belle
Rosiclare	Memphis
Spivey	Pygmy
Victory #1	Yandell
West Green #1	

(1) Producers of crystal specimens for collectors (in part, Weller *et al.*, 1952)
(2) Major zinc producers
(3) Active at the time of writing
(4) Reopened in 1989 as the Ozark-Mahoning mine #1

remain of minor importance for the foreseeable future. Fluorine resources are widespread in the United States, but very few deposits are economically significant.

Large quantities of zinc, as well as some lead and barite have been produced at some mines, usually as by-products of fluorite production. Road gravel made in heavy-media milling operations was also an important by-product; with purple pebbles here and there, some country roads (and almost all mine roads) are interesting to walk over. Silver can be recovered from galena, and cadmium and germanium from sphalerite. From 1880 to 1979, over 12 million tons of fluorite have been shipped from the district. More than 7 million tons of that total have come from the Illinois side (Trace, 1974a).

To describe the individual histories of each of the more than 200 mines in the district would be impractical here. The 17 mines discussed below were important producers or were of special interest. (See Table 3 and Figure 13 for a more complete list of the various mines and their locations.)

Insomuch as the owners, Ozark-Mahoning, were the only domestic producers of fluorite due to the cheap price of imported ore, they were effective in maintaining the costs of operations by establishing the mine, most mining equipment and mine structures utilizing "in-house" personnel (Evans and Hellier, 1986). The Annabel Lee and No. 1 mines were the last active fluorite mines in the United States; both closed in 1995.

Babb mines

The Babb fault system has been intensively studied and mined from the beginning of this century to the present. The three largest mines (as of 1950) had produced a total of about 138,000 tons of fluorite (Swanson and Starnes, 1950). Later work by F. B. Moodie, III on the Eagle-Babb and Barnes properties indicated the potential for an additional million tons of ore (Moodie and McGrain, 1974).

The Kentucky-Babb mines utilized four shafts to remove an estimated 56,000 tons of fluorite. Extensive stoping was carried out as deep as 550 feet. Although veins ranged from 10 to 30 feet wide, fluorite lenses were generally less than 12 feet wide. Many of the fluorite pockets were essentially free of calcite, while calcite rarely contained more than 10% fluorite (Hardin, 1955).

Work carried out in late 1971 to early 1972 included the drilling of some 45 holes in order to determine the potential ore deposits on the Eagle-Babb and Barnes properties. Data obtained indicated vertical fissure fills with an average width of 9 feet, and height varying from 200 to 400 feet. The hanging wall of the Babb fault was followed for more than 5,000 feet. As is typical with vein mines in the district, the best ore deposits were found in the St. Louis and Ste. Genevieve limestones. A shaft was later sunk, although no information is available. If mining resumes in Kentucky, it is likely to be here.

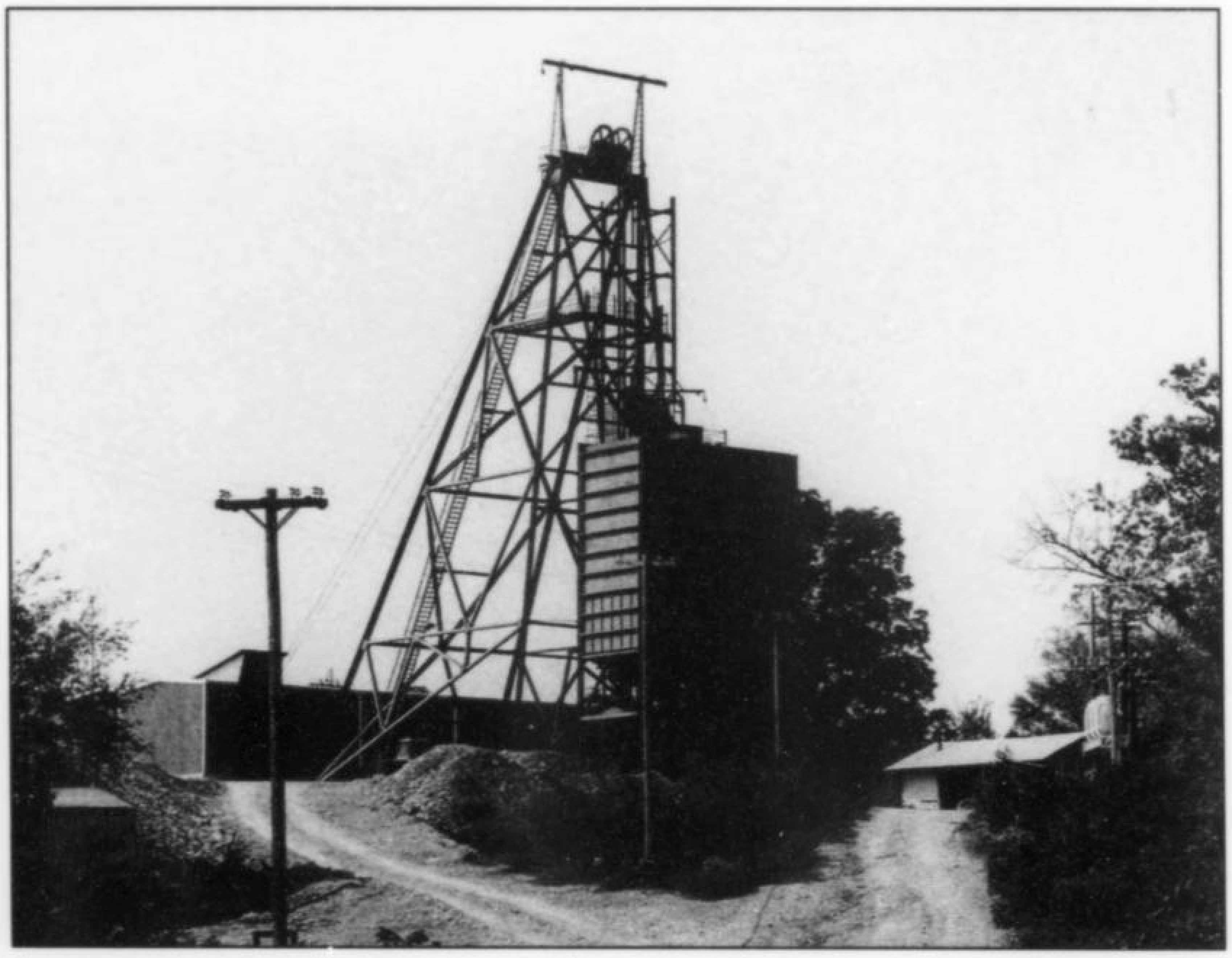


***Figure 3.* The Annabel Lee mine, 1986. Author's photo.**

Annabel Lee mine

The Annabel Lee mine, located north of the Rock Creek Graben, was the last mine to be opened in the district and produced many beautiful specimens for collectors. The headframe sat on the Palestine sandstone; the shaft is 996 feet deep. Ore was produced from the Downeys Bluff limestone (beneath the Bethel sandstone), the Joppa member and Spar Mountain member (the "sub-Rosiclare horizon") of the Ste. Genevieve limestone (E. Livingston, personal communication). These are the same horizons exposed in the surface mines on Spar Mountain, 4 miles south. The name "Annabel Lee" was derived from Edgar Allen Poe's poem of the same name (J. M. Fowler, personal communication).

The shaft was sunk 900 feet south of one orebody and 1500 feet north of another. The north and south orebodies were separated by a fault associated with the Rock Creek Graben, hence their different elevations. As is the case with most of the Cave in Rock mines, the Annabel Lee is in bedding replacement deposits. Mining is carried out by the room and pillar method.

Big Four mine

Located on the Big Four fault system, the Big Four mine was opened in 1898 by J. C. Miller (Fohs, 1907). Until 1905, zinc-bearing "gravel spar" was mined from an open cut. In 1917, A. H.

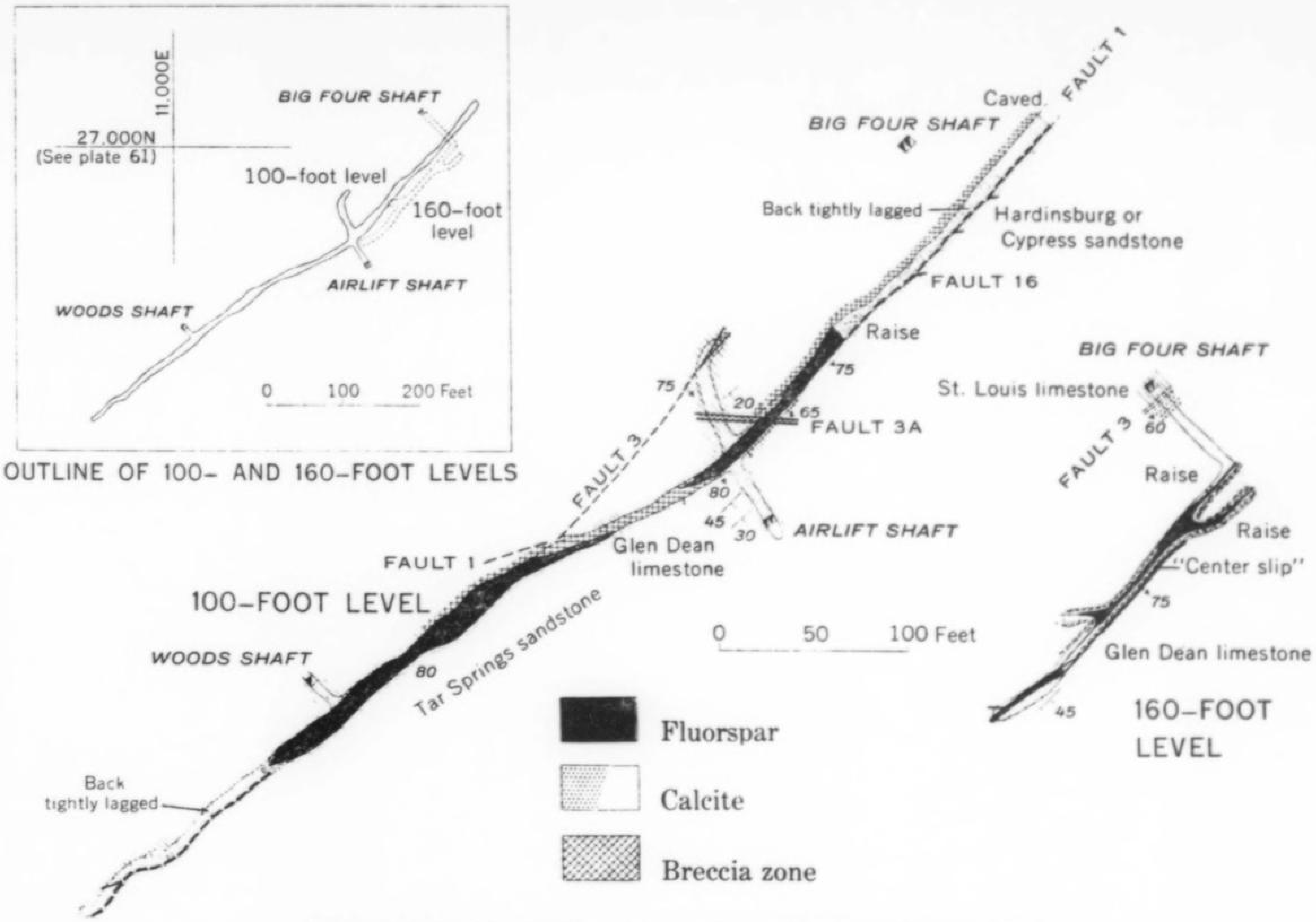


Figure 4. **Plan of the Big Four mine workings (Hardin and Trace, 1959).**

Reed, Sr. expanded operations by deepening the surface mine and sinking two 100-foot shafts (the Big Four and Airlift). The mine closed following World War I, but reopened from 1922 to 1924, organized as the Big Four Fluorspar and Ore Company (Hardin and Trace, 1959). Drifts were established on the 100-foot level.

In 1924, mine ownership was transferred to the Lafayette Fluorspar Company, which deepened the Big Four shaft to 200 feet, then closed the mine. In 1944, Perry and Loyd acquired a lease on the Big Four mine, and established a cross-cut to the vein and set a drift at the 160-foot level. From this level, a raise was driven above to the 100-foot level. The next year, the Woods shaft was sunk 400 feet southwest of the Big Four shaft and connected to the 100-foot level of the Big Four shaft.

The Big Four mine produced over 35,000 tons of fluorite prior to 1946. Lead and zinc (not abundant anyway) were not mined due to inadequate milling facilities.

Blue Diggings mine

The Blue Diggings mine tapped into the Blue Diggings vein via major shafts including the Fairview, Blue Diggings and Last Chance. The deepest was the Fairview shaft at 800 feet. Drifts and stoping were carried out extensively along the Blue Diggings vein.

The Blue Diggings vein lies 900 feet west of and generally parallel to the Rosiclare vein. Unlike most veins in the district, this one dips 65° eastward. It is rather narrow, averaging less than 3 feet in width, with occasional swells to 8 feet. Significant fluorite deposits were found at depths of nearly 750 feet. Major drifts were made at the 300, 400, 500, 650 and 750-foot levels. The 800-foot level was for the most part barren of fluorite. The deeper levels of ore were found in the 1940's by extensive diamond drilling.

Columbia mine

Located in Kentucky, the Columbia mine has the distinction of being the oldest in the district. A company owned by Andrew Jackson sank a shaft 40 to 60 feet deep, searching for argentiferous galena. About 30 years later, the Columbia Silver Mining Company purchased the mine and deepened the shaft to 80 feet. In 1873 or 1874, the mine was leased to Halliday and Green who, in the course of 15 months, ran a drift at the 50-foot level. The Glass family took an option in 1875 and deepened the shaft slightly, running drifts and setting up facilities to sort and smelt lead. The operations closed the following year due to the decline in the value of lead. Operations resumed at the turn of the century, sinking a shaft now 140 feet deep, with major drifts at the 80 and 135-foot levels.

The Columbia mine is developed on the Levias-Crittenden Spring fault system, with Ste. Genevieve limestone on the footwall and Chester-age shales and sandstone on the hanging wall. Most ore occurs in the footwall, with deposits of calcite and brown fluorite, and replacement of limestone by sphalerite. Galena also occurs sporadically. There is very little secondary mineralization, except for occasional coatings of greenockite. Department of the Interior reports for 1944 estimate that 35,000 tons of fluorite, sphalerite and galena have been removed from the property. Property owner Bill Frazier is presently (summer 1996) exploring the Columbia, Hutson and Old Jim mines for ore.

Crosson Cave prospect

The Crosson Cave prospect is interesting because its occurrence is atypical in the fluorspar district. While the Ste. Genevieve

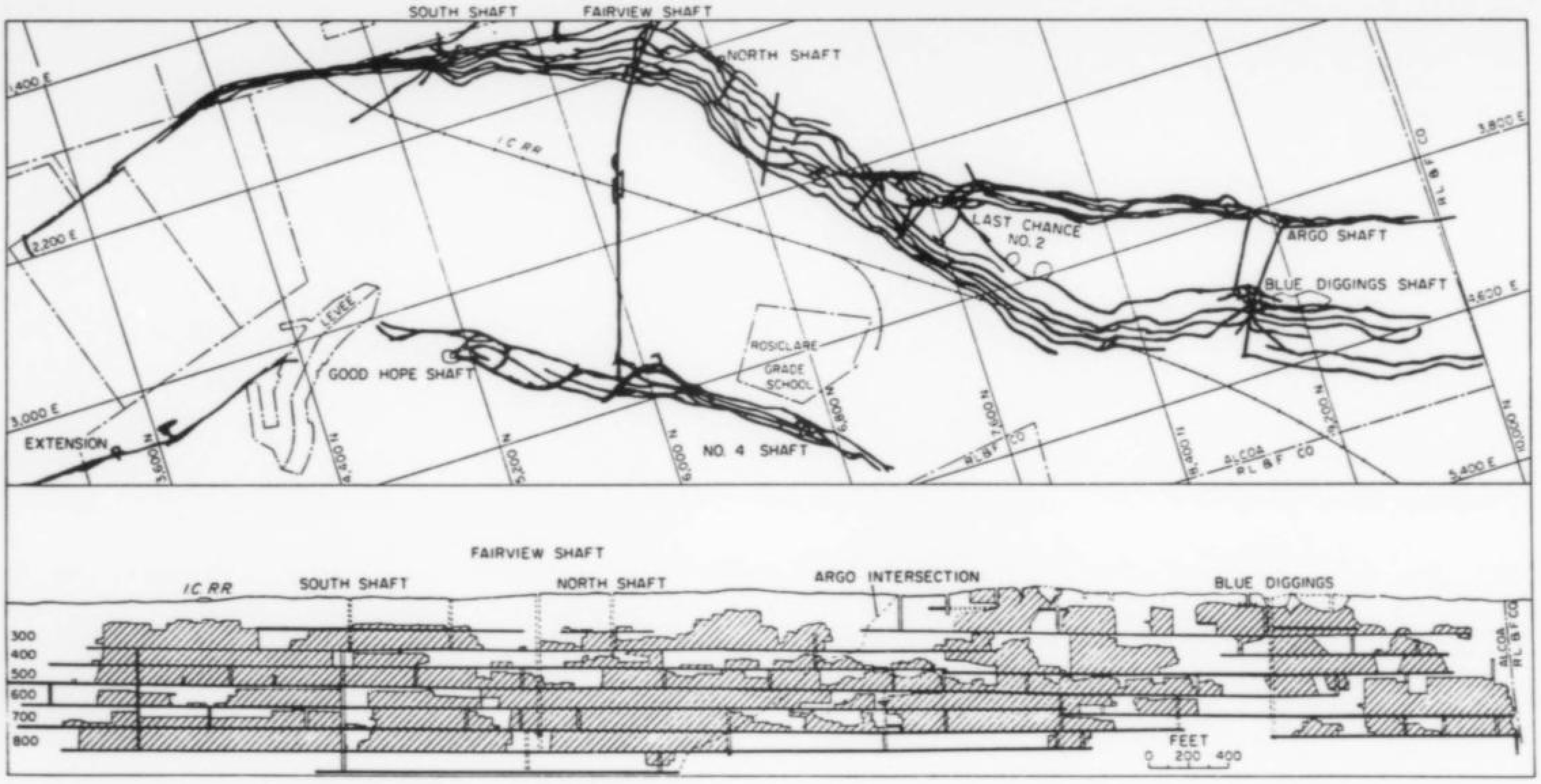


Figure 5. **Plan and cross-section from the South shaft and North shaft (Fairview mine) to the Blue Diggings mine (Grogan and Bradbury, 1968).**

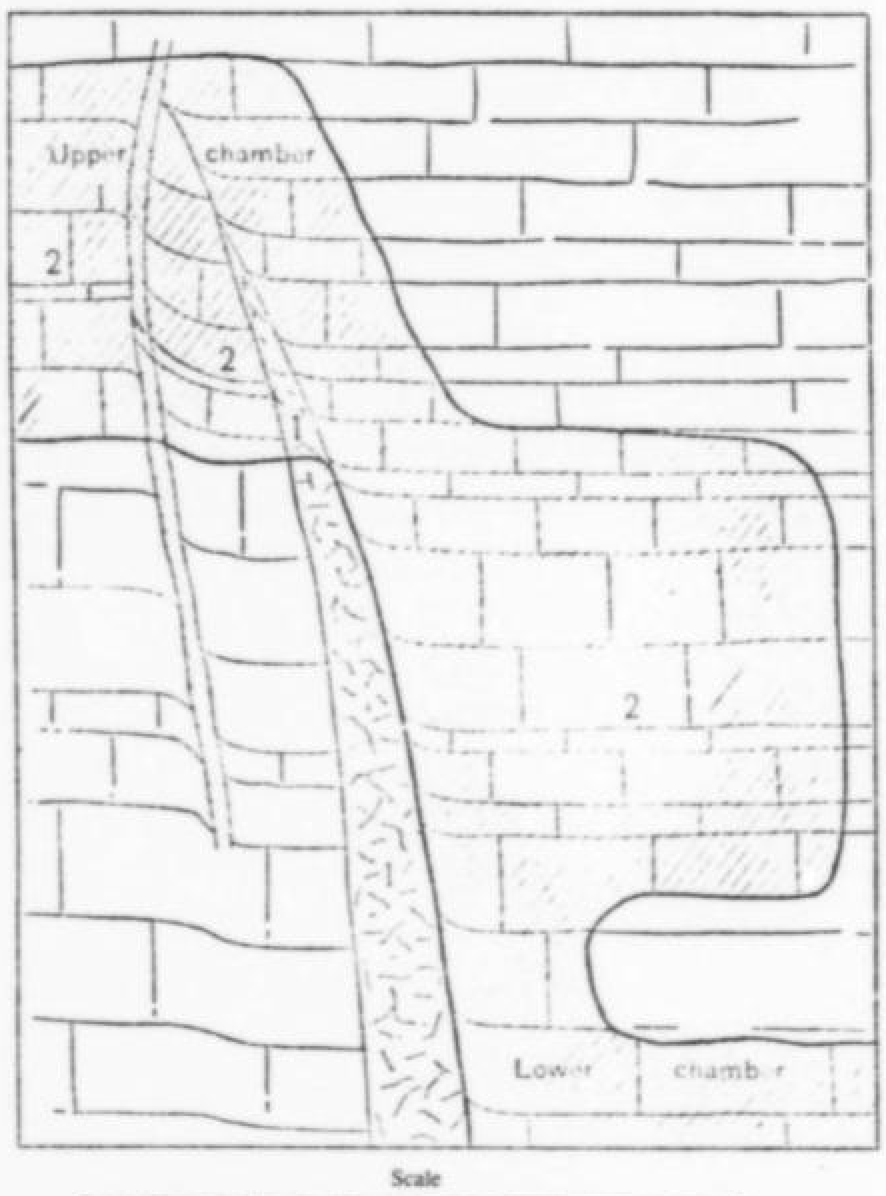


Figure 6. **Cross-section through Crosson Cave (2 = fluorite vein, offset by faulting) (Ulrich and Smith, 1905).**

limestone occurs throughout the district (in a patchwork pattern due to faulting), and while caves are relatively common in this limestone formation, caves with mineralization (fluorite, etc.) are very rare. The Crosson Cave prospect is a cave that intersects two veins of fluorite. According to Ulrich and Smith (1905):

The surface is a broad sink hole about 10 feet deep, at the bottom of which are two openings into the cave. In this, so far as explored, there are two chambers, an upper and a lower. The first floor is 11 feet below the entrance . . . , the other is 42 feet below this floor. In the lower chamber there is a stream of flowing water. The two surface openings, 14 feet apart, have been formed on a vein with a course of N10°W. The single opening which joins the upper and lower chambers has formed in the obtuse angle between this vein and a second with a trend of N37°E.

Both of these veins fill fissures due to faulting, although in both cases the amount of faulting is small. The throw of the northwestern fault, as seen on the north wall of the upper level, is 2 feet 11 inches, while that of the northeastern fault, seen at the same level, is a little over 7 feet. The northwestern vein dips toward the east at an angle ranging from 70° to 81° at the upper level to approximately vertical at the lower level. Its width varies from about 8 inches to a little more than 2 feet; it is composed of fluorite, calcite, and some barite. The northeastern vein has a southerly dip ranging from 65° at the upper level to about 84° at the lower. Its width is nearly 3 feet in the lower chamber, while it pinches in the upper. This vein, like the other, is composed of fluorite, calcite and barite.

Daisy mine

The Daisy mine was operated by the Rosiclare Lead and Fluorspar Company on the Daisy vein. This vein lies some 600 feet west of the northern part of the Rosiclare vein. It was rarely wider than 8 feet, although it was reported to be wider than 20 feet in a few places (Bastin, 1931).

In 1926 the mine shaft was over 400 feet deep, with drifts at the 180, 300 and 412-foot levels. A winze led to a drift near the 500-foot level. Before the mine was closed in 1941, an 800-foot level was worked, a result of lateral diamond drilling from the Rosiclare mine (Weller *et al.*, 1952). The southern part of the vein was mined out from the adjacent Blue Diggings vein. The largest ore shoot was 2,000 feet long, 250 feet high, and averaged 3 feet in width (Grogan and Bradbury, 1967).

The west (hanging) wall of the Daisy vein shows evidence of fault movement post-dating the deposition of fluorite. Fractures due to faulting were found to traverse and brecciate the fluorite and calcite in some places (Bastin, 1931). Slickensides indicate movement occurred at different times. In addition, evidence of wall rock replacement has been found.

Denton Mine

The Denton mine, like the nearby Annabel Lee mine, was operated by the Ozark-Mahoning Company in the relatively recently developed Harris Creek district. The deposits here, on the up-thrown north side of the Rock Creek graben, are all stratiform replacement bodies; they have been exploited along three major horizons known as the Bethel, Rosiclare, and Sub-Rosiclare levels. Eric Livingston (personal communication, 1996) reports several 100 to 150-foot collapse features in this mine which are similar to possible conduits for ore-forming solutions described by Brecke (1962, 1982).

Production began at the Denton mine in November of 1979 (Lillie, 1988), and ceased with the depletion of ore reserves in 1993. During its brief period of operation the Denton mine was one of the most important specimen producers in the Illinois-Kentucky fluorite district, yielding not only thousands of fine fluorite specimens but also the greatest variety of calcite crystal habits and associations of any mine in the district.

Dyers Hill mine

Located 3.5 miles north of Smithland, the Dyers Hill mine might be considered an outlier in the district. It was established after numerous diamond drill cores were taken along the hanging wall of the Dyers Hill fault. Exploration began in 1950 and was completed by 1952. Tibbs (1974) reported that "the main Dyers Hill fault was found to be mineralized with fluorspar for a distance of 4,200 feet overall, and varied from 1 foot to over 30 feet in width. It had an economic minable depth of about 400 feet."

Dominant components in the main vein are fluorite, calcite, sedimentary rocks, and aragonite (?). Barite was found in minor concentrations near the top of the deposit, some 200 feet beneath the surface. Sphalerite and galena are minor components (less than 3%). Very little crystalline fluorite was found. It is mainly massive and colorless to brown. At the northeast end of the mine, voids containing dogtooth calcite crystals up to 18 inches in length were found (Tibbs, 1974).

Ore was mined by shrinkage stoping at the 350, 520 and 690-foot levels. Production of 85 tons a day was reached in 1956, and a maximum of 550 tons per day was reached in 1965. By 1968, the mine had become unprofitable and was closed.

Eagle-Watson mine

Capt. D. G. Hearne began prospecting the Eagle-Watson property in 1917 (Starnes and Hickman, 1946). "Gravel spar" deposits were found throughout the property at depths of up to 120 feet. The Moore Hill fault system crosses through the property, with a network of vein-bearing smaller faults. Weathering left a large concentrate in the residuum. Starnes and Hickman noted that more than 90% of the estimated 200,000 tons of fluorite produced was mined at depths of less than 200 feet. They reported that in drifts at the bottom of the 300-foot Main shaft, a 7-foot vein was found. A two-inch streak of fluorite was visible, the remainder consisting of calcite.

In addition to the 300-foot Main shaft were the 260-foot No. 2, the 250-foot Red Headframe and 260-foot Green Headframe shafts.

Hickory Cane mine

The history of the Hickory Cane mine property, located along the Commodore fault zone, dates back to about 1901. Shafts have produced both fluorite and zinc; the deepest on the property is the Rock shaft, 240 feet deep. The Rock shaft has levels at 25, 60, 120, 155, 160, 200, and 240 feet. Between the 60 and 160-foot levels a considerable amount of stoping was done. A 4 to 5-foot zone of galena occurred from the 160 to the 240-foot levels. Between 7,000 and 8,000 tons of smithsonite was removed from the Hickory Cane mine between 1924 and 1925 (Trace, 1954a, b).

Figure 7. **Rock shaft area, Hickory Cane mine. Author's photo**

The dump of the Rock shaft contains smithsonite, galena, sphalerite, small amounts of cerussite and hemimorphite. Calcite is, by far, the most abundant mineral found on the dump. Leaching has formed white botryoidal-like calcite deposits. Fluorite is very sparse.

On the southern part of the property, the 35-foot-deep Maddox shaft was sunk in late 1941 and early 1942 to remove "gravel spar" (about 215 tons of fluorite). The shaft was later deepened to 60 feet. A crosscut was made to a fluorite vein on the Commodore fault. In 1945, a vertical raise was cut, called the Yandell shaft. The fault zone in this area contained mud, gouge, calcite, fragments and veins of fluorite and disseminated sphalerite and galena (Trace, 1954a, b).

In 1944 the Null shaft was sunk to a depth of 44 feet. A property line dispute halted operations.

Hillside mine

The Hillside mine taps into the Hillside vein, containing a deposit of fluorite that was continuous for more than 1,600 feet. The nearly vertical vein trends in a north-south direction and varies from 5 to 35 feet in width (Bastin, 1931). This is one of the widest vein widths in the district.

In 1920, the Hillside Fluorspar Mines Company sunk the Hillside shaft to extract ore. Production began two years later. The shaft was 6 by 20 feet across and 520 feet in depth. It needed to be concrete-lined, due to weathering of bedrock, to a depth of 182 feet (Bastin, 1931). Major drifts were at the 170, 250, 350, 450, 550, and 650-foot levels. The 350-foot level follows the vein for 1,600 feet. A 450-foot-deep 6 x 12-foot shaft was placed 900 feet north of the main shaft, connecting with the 250 and 350-foot levels. It provided ventilation and ore hoisting. Operations ceased in 1937 when ores in the 500 and 650-foot levels were depleted (Weller *et al.*, 1952).

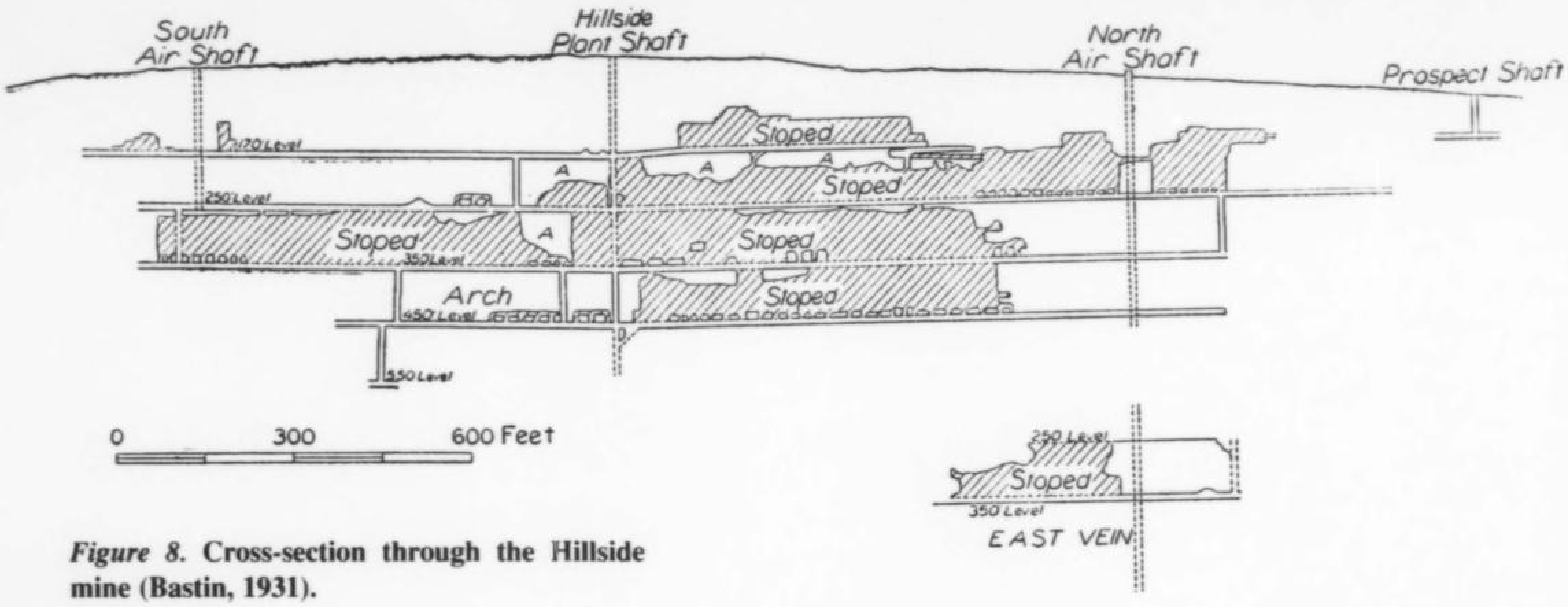


Figure 8. **Cross-section through the Hillside mine (Bastin, 1931).**

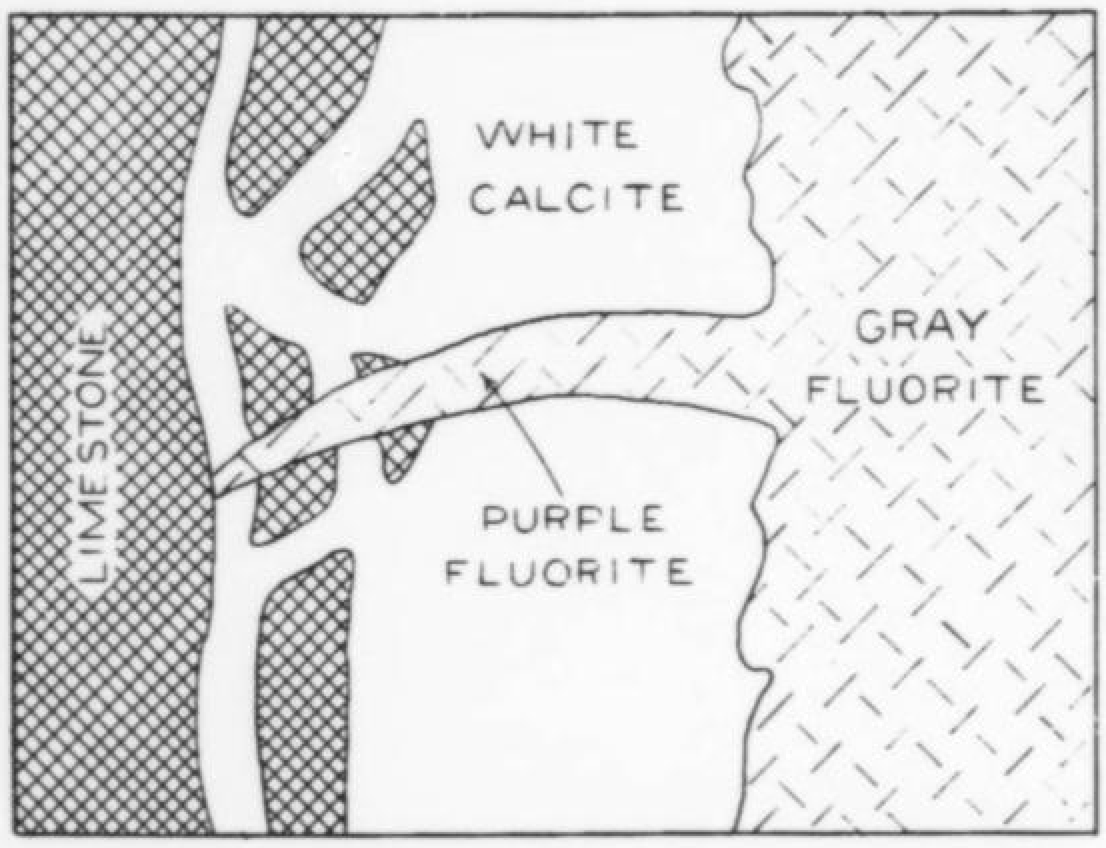


Figure 9. **Diagrammatic sketch showing veinlet of fluorite traversing vein calcite and limestone inclusions. The main vein is here 3 feet wide with a central $2^1/_2$ feet of gray fluorite. Hillside mine, 250-foot level, 750 feet north of shaft cross-cut. (Bastin, 1931)**

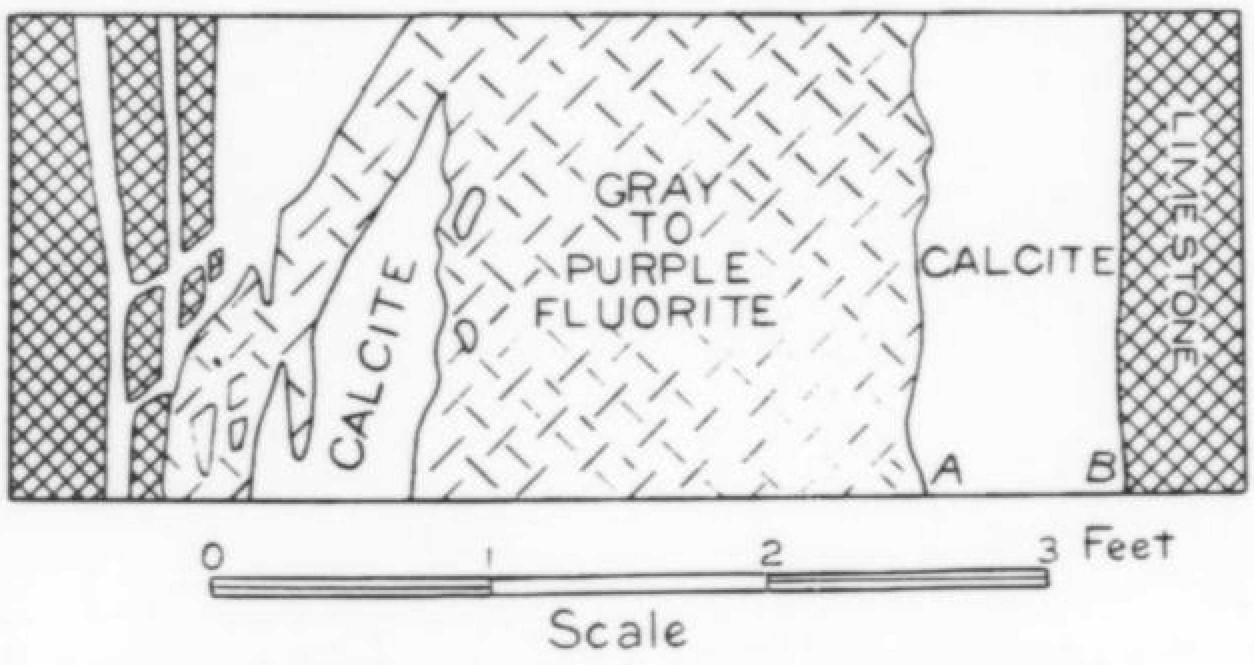


Figure 10. **Diagrammatic sketch showing entire width of vein 800 feet north of shaft cross-cut on 250-foot level of the Hillside mine. Fluorite occupies the center of the vein, branches into the calcite and encloses a few angular fragments of calcite. The contact (A) between fluorite and calcite is irregular, and what appear to be straight crystal faces of calcite project into the fluorite. The contact between limestone and calcite (B) is a tight "frozen" contact. (Bastin, 1931)**

Vein contacts throughout most of the mine were said to be "firmly attached to both limestone walls" (Bastin, 1931). Slickensides were minor. Visual inspection within the mine shows little evidence of replacement of wall rock. The appearance of stylolites in both ore and wall rock indicate that replacement may have been important.

Lead concentrates were shipped to the National Lead Company to be smelted. Silver in the galena averaged 5 ounces to the ton.

Hutson mine

The Hutson (or Hudson) mine was worked for fluorite along with the Pierce prospect before 1900. Ulrich and Smith (1905) reported a caved shaft and open cut abandoned at the time of their visit (about 1903). They reported fluorite in a vein 6 inches to 4 feet thick.

Currier's report some 20 years later discusses operations by the American Fluorspar Company as involving 2 shafts and a 200 x 150-foot, 75-foot-deep open cut. The pit, crossed by two lamprophyre dikes, consisted at that time of a body of smithsonite. Before being abandoned, the open cut measured 400 x 200-feet.

Oesterling (1952) gave the most detailed account of the Hutson mine: Between 1914 and 1945 about 30,000 tons of smithsonite and 23,000 tons of sphalerite were extracted. In 1946, Alcoa purchased the property and, three years later, sunk a 523-foot shaft. Drifting at the time of Oesterling's paper was taking place on the 300 and 425-foot levels. The older drifts on the 90, 140 and 200-foot levels had been abandoned. The 90-foot level contained a 105 x 145-foot stope beneath the open cut. An 800-foot-long drift intersected a raise to the stope at the 90-foot level. About 1,450 feet of drifting was done on the 200-foot level.

The lamprophyre dikes at this mine are separated by 110 feet at the 200-foot level and by 84 feet at the 425-foot level. Both have been affected by faulting. The west dike is 8 to 9 feet wide at the 425-foot level and is of a dark green color. At the same level, the east dike is considerably narrower, and is a pale green color.

The ore from the Hutson mine varied from 9.8 to 39.2% metallic zinc. Sphalerite was found as both vein and bedding replacement deposits. In areas where sphalerite was mined, fluorite was absent. Marcasite was found in sizable quantities, apparently emplaced prior to, and with the sphalerite.

This mine is unique in showing almost a complete sequence of geological activity that is generally seen only piecemeal elsewhere throughout the district.

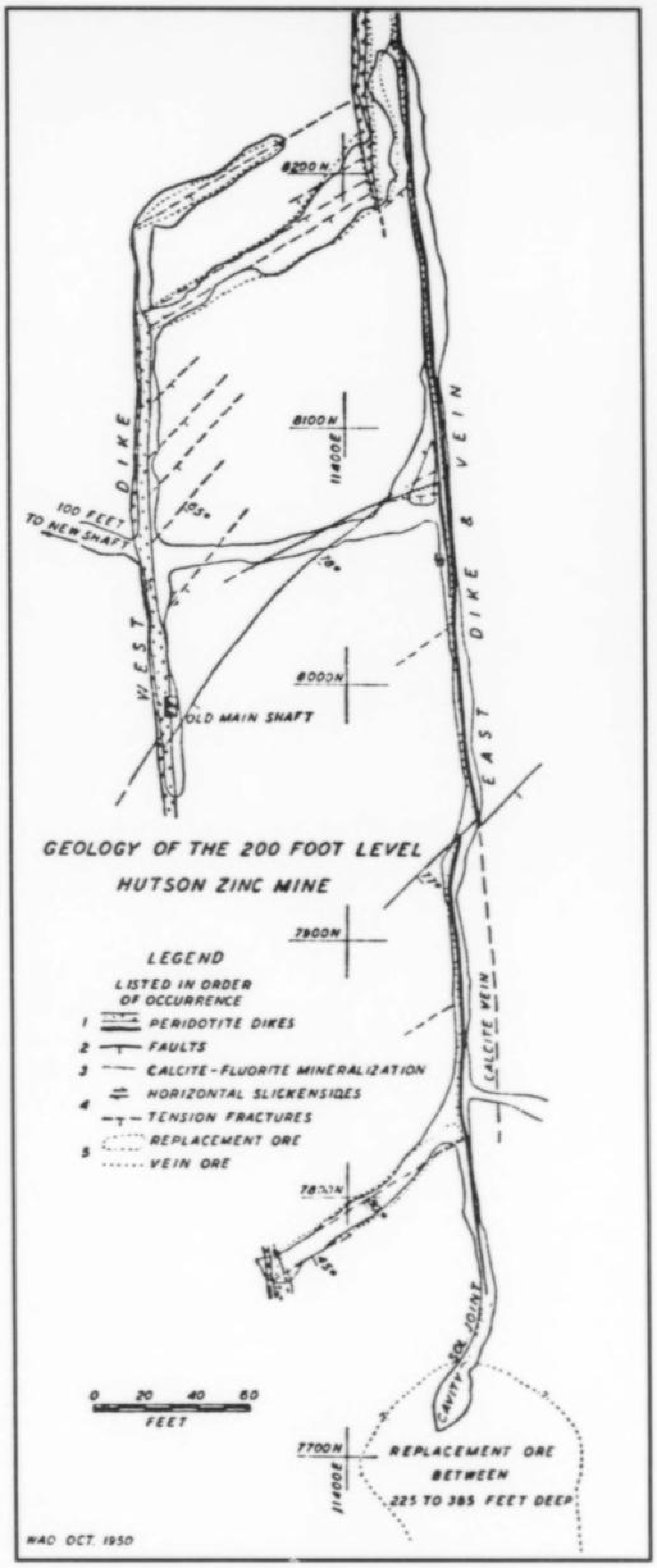


Figure 11. **Plan of the Hutson mine workings (Oesterling, 1952).**

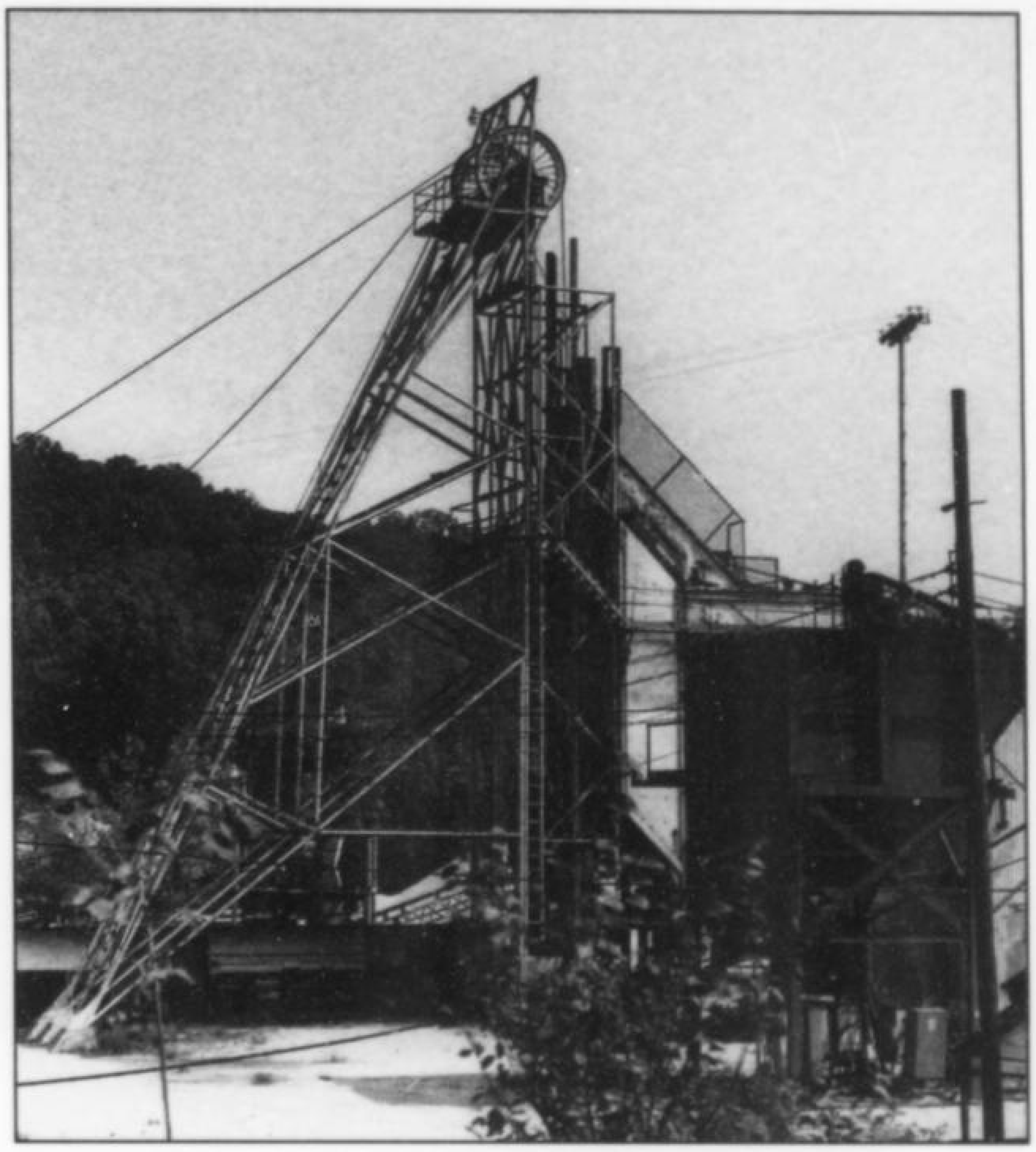


Figure 12. **The Minerva #1 shaft and mill, 1986.**

Mary Belle mine

The Mary Belle mine is located a quarter mile south of the Columbia mine, and is associated with the same fault system. The sulfide minerals were subordinate to fluorite here.

Small diggings were reported from the middle 1800's, but it was not until the turn of the century that the first shaft was sunk, yielding over 500 tons of fluorite within the first nine months (Ulrich and Smith, 1905). Although the history of the mine is sketchy, by the late 1920's the main shaft was 350 feet deep. Drifts were located on the 200 and 250-foot levels. The vein was reported to vary from 4 to 10 feet wide for over 700 feet without the dramatic pinches and swells common in other mines. Department of Interior reports for 1944 indicate that 65,000 to 75,000 tons of fluorite have been mined.

Minerva No. 1/Ozark-Mahoning No. 1 Mine

Located north of Cave in Rock, this mine tapped the largest bedding replacement orebodies ever found in the United States, a structure some 20,000 feet long. This orebody, discovered by churn drilling in 1940, also has the distinction of being one of the few deposits ever discovered in which sex played an essential role in the find. According to retired mine manager Gill Montgomery, the drill operator in 1940 had chosen to work the third (late) shift so that he would be able to sneak out unseen for romantic liaisons with his girlfriend while the drill ran. Time went by, however, and no ore was found. Management was consequently preparing to pull out of the area, a move which would deprive the drill operator of his convenient nightly opportunities for rendezvous. In order to stave off this problem he took several buckets of high-grade fluorite ore from stockpiles at the mill and "salted" his churn cuttings in order to create the hint of a new find. The geologists were fooled, and ordered another hole to be drilled. That was the hole which first penetrated the Minerva No. 1 orebody!

The Minerva Oil Company sunk a 640-foot shaft in 1942, and extraction began the following year on the southwest orebody. In 1944 operations began on the northeast orebody. In 1975 Allied Chemical Company purchased the mine, but closed it down the following year. Seaforth Minerals and Ores Company purchased the mine in 1982, and sold it to the Ozark-Mahoning Company in 1988. Pumps operating around the clock required nearly a year to remove an estimated *one billion gallons* of water (Eric Livingston, personal communication). Ore removal finally began again in 1989, and continued until 1996 when the pillars on the 1,600-foot level were robbed and the mine was shut down.

Although the strataform deposits are roughly flat-lying they have been tilted to some degree by Hicks Dome. The shallow southeast orebody contained all of the significant sphalerite deposits; fluorite became dominant where the strata were replaced at greater depths. Inclined shafts were required for access to the deeper Rosiclare and Sub-Rosiclare levels. When the price of fluorite would decline, mining activities shifted to concentrate on the large sphalerite deposits. This flexibility permitted the mine to stay in operation continuously for 33 years.

Because of the change in ownership of the mine, mineral specimens recovered before 1977 are generally identified as having come from the *Minerva* No. 1, whereas specimens found after 1988 are labeled *Ozark-Mahoning* No. 1. This orebody provided some of the most spectacular specimens ever found in the district: world-class examples of fluorite, witherite, benstonite, strontianite and barite.

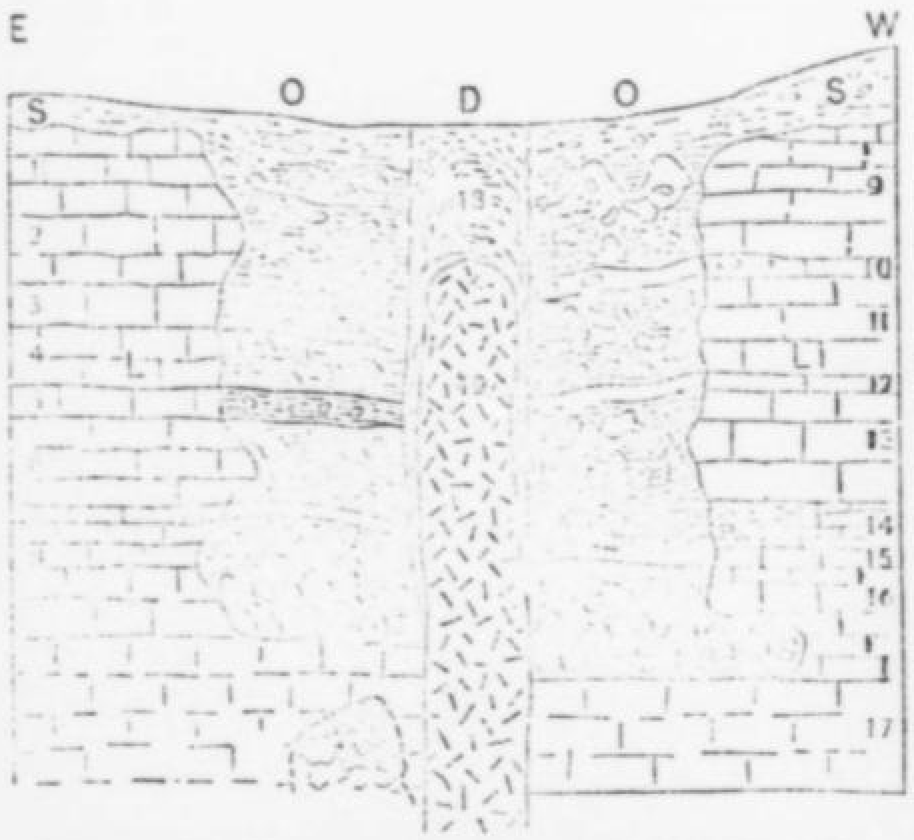


Figure 13. **Cross-section through the Old Jim mine (Ulrich and Smith, 1905).**

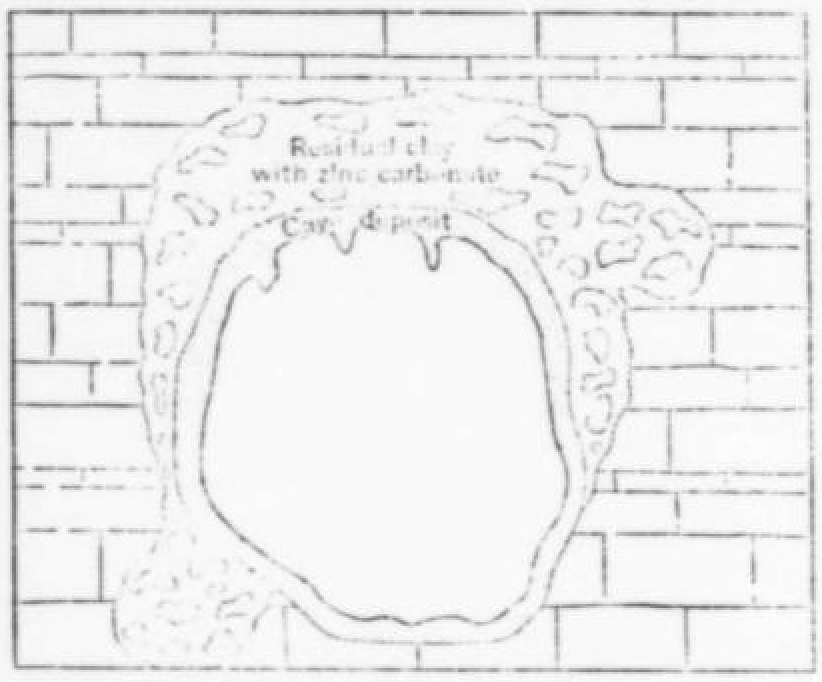


Figure 14. **Cross-section through a cave intersected by the Old Jim mine (Ulrich and Smith, 1905).**

Old Jim mine

Located about 4,000 feet south of the Columbia mine is the Old Jim mine, one of the three most noteworthy zinc mines in the Kentucky portion of the district. The zinc orebody was discovered in 1900 and mining began the next year; it was near-surface, and predominately smithsonite, though hydrozincite and disseminated sphalerite were also extracted in modest quantities.

A noteworthy feature of the Old Jim mine was its association with a narrow but continuous lamprophyre dike. The Hutson mine, located 11 miles to the southwest, exploits a similar though more extensive deposit and is also associated with lamprophyre dikes.

The mine consists of two open cuts. The northern cut is 400 feet in length and 37 feet deep. The southern cut is only 140 feet long. Smithsonite replaced the Ste. Genevieve limestone in the form of bedding replacement. Even chert nodules had some zinc content.

The southern cut trends to a sink hole containing a small cave. The walls of the cave were covered with typical calcite speleothems (cave formations), but behind the cave walls were residual deposits rich in smithsonite. The cave was mined out.

Pygmy mine

Five miles east of the Yandell mine, on the Tabb fault system, is the Pygmy (or Pigmy) mine, actually a series of shafts and open cuts. Abandoned now, this mine is perhaps the best-exposed fluorite/barite mine in the Kentucky portion of the district. In addition to material on the dumps, exposures of steeply dipping

Figure 15. **The Pygmy mine in 1919. Edwin Reeder photo, courtesy of Mary Hardin.**

Figure 16. **Pygmy mine open cut, 1986. Author's photo.**

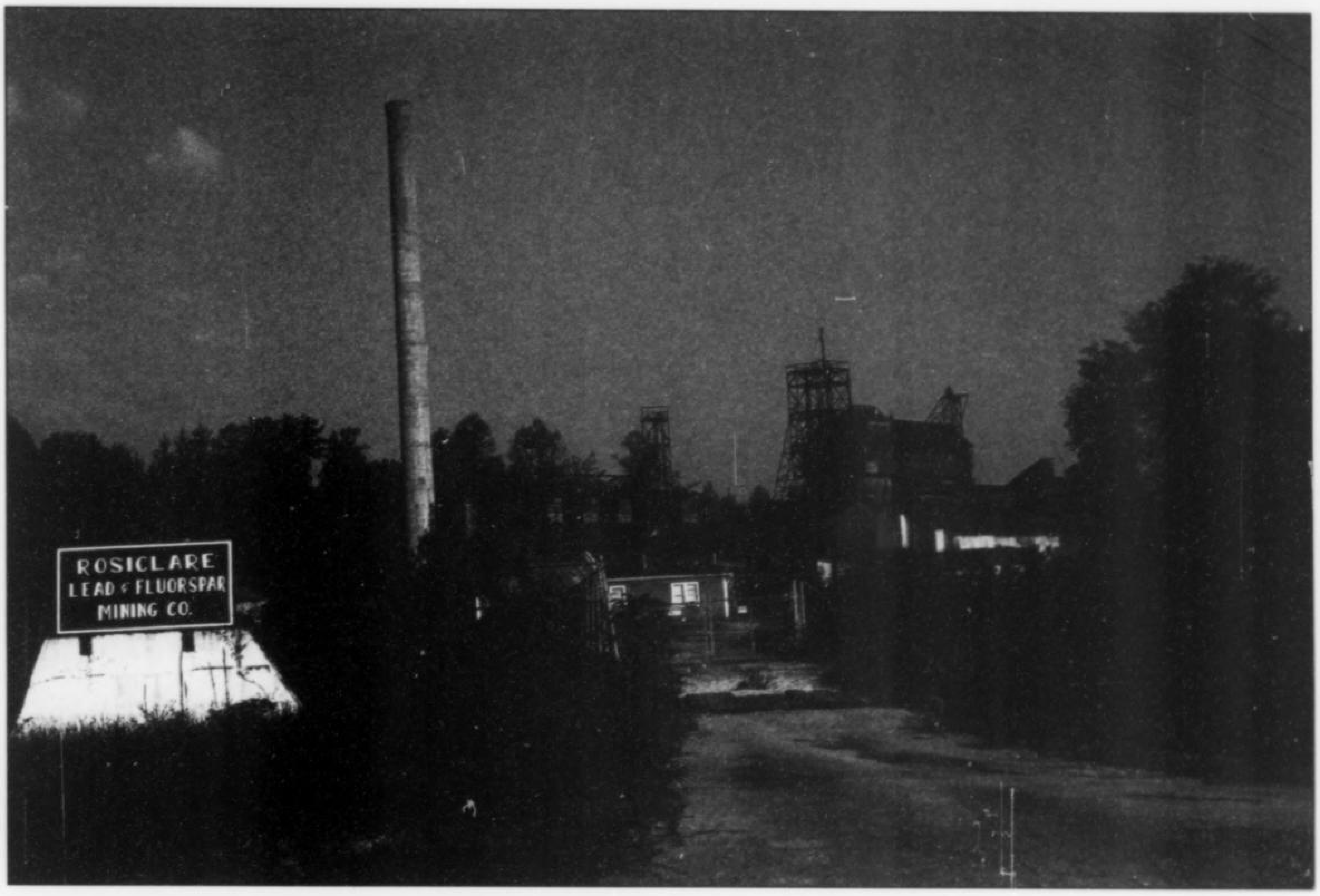


***Figure 17.* The (abandoned) Rosiclare Lead and Fluorspar Company plant and shaft in 1986. Author's photo.**

strata on the Tabb fault system are visible. The writer observed an open shaft during a Spring, 1986 visit which was not exposed during a visit three years earlier. This points out the need to exercise caution when visiting old mines. Current regulations require a thick concrete cap over the shafts, as well as the dismantling of headframes. Older shafts frequently were insufficiently covered or left open. The Pygmy area is riddled with no fewer than 14 shafts.

The Pygmy area was first mentioned by Ulrich and Smith as the "Myers prospect." It consisted at that time of several open cuts and shallow shafts that exposed a 200-foot-wide residuum zone of barite and minor fluorite. Hoeing (1913) described a 100-foot Pygmy shaft, with drifts at the 60 and 100-foot levels.

In 1915 the property was purchased by the Rosiclare Lead and Fluorspar Company. A single 150-foot shaft with a 300-foot drift was reported (Trace, 1985). Two shafts, the No. 1 and No. 6 were sunk to 220 and 300 feet, respectively. The No. 1 shaft was reported to have a 680-foot drift and a 200-foot-long crosscut at the bottom. Additional drifts were at the 50, 90 and 150-foot levels. The No. 6 shaft had crosscuts and drifts at the 110 and 330-foot levels. Operations were discontinued in 1919 after removing 15,000 tons of fluorite.

Henry and Frazier reopened the Pygmy briefly in 1928–1929, removing 2,000 tons of ore from five shafts (Trace, 1985).

J. S. Frazier sunk six shafts of varying depths (50 to 150 feet) on the property from 1936 to 1941. Additional shafts were sunk later, but no information is available. Total production from 1936 to the early 1950's could have been as much as 73,000 tons.

The property was leased to J. W. Crider in the mid to late 1950's. The main operation was an open cut mine which continued intermittently until 1973. Crider's strip mine followed the fault zone for 1,500 feet. Draglines removed an estimated 15,000 tons of fluorite and an additional 15,000 tons of barite from shallow deposits 100 to 200 feet wide. These cuts are readily visible today.

Rosiclare mines

The most productive vein mines in the district have been associated with the Rosiclare vein, which extends from beneath the Ohio River northward for about 2 miles. The southern part of the vein was mined by the Franklin Fluorspar Company (Alcoa). The Good Hope and Extension were two major shafts, with additional ore removed through the Annex, the New and the No. 4 shafts. Widths at this part of the vein varied from 4 to 12 feet, with a maximum of 20 feet near the surface.

The northern part of the vein was mined by the Rosiclare Lead and Fluorspar Mining Company. On this section of the vein were the Rosiclare shaft, Rosiclare Plant shaft, and the Air shaft. Maximum vein widths were 25 to 30 feet, but averaged 5 to 6 feet. The vein was mined continuously for 4,850 feet (Grogan and Bradbury, 1967).

As was typical for the vein deposits in this area, fluorite in the Rosiclare vein pinched out at depth, becoming calcite. The depth at which the fluorite "bottoms out" into calcite varies from about 300 to 720 feet in depth.

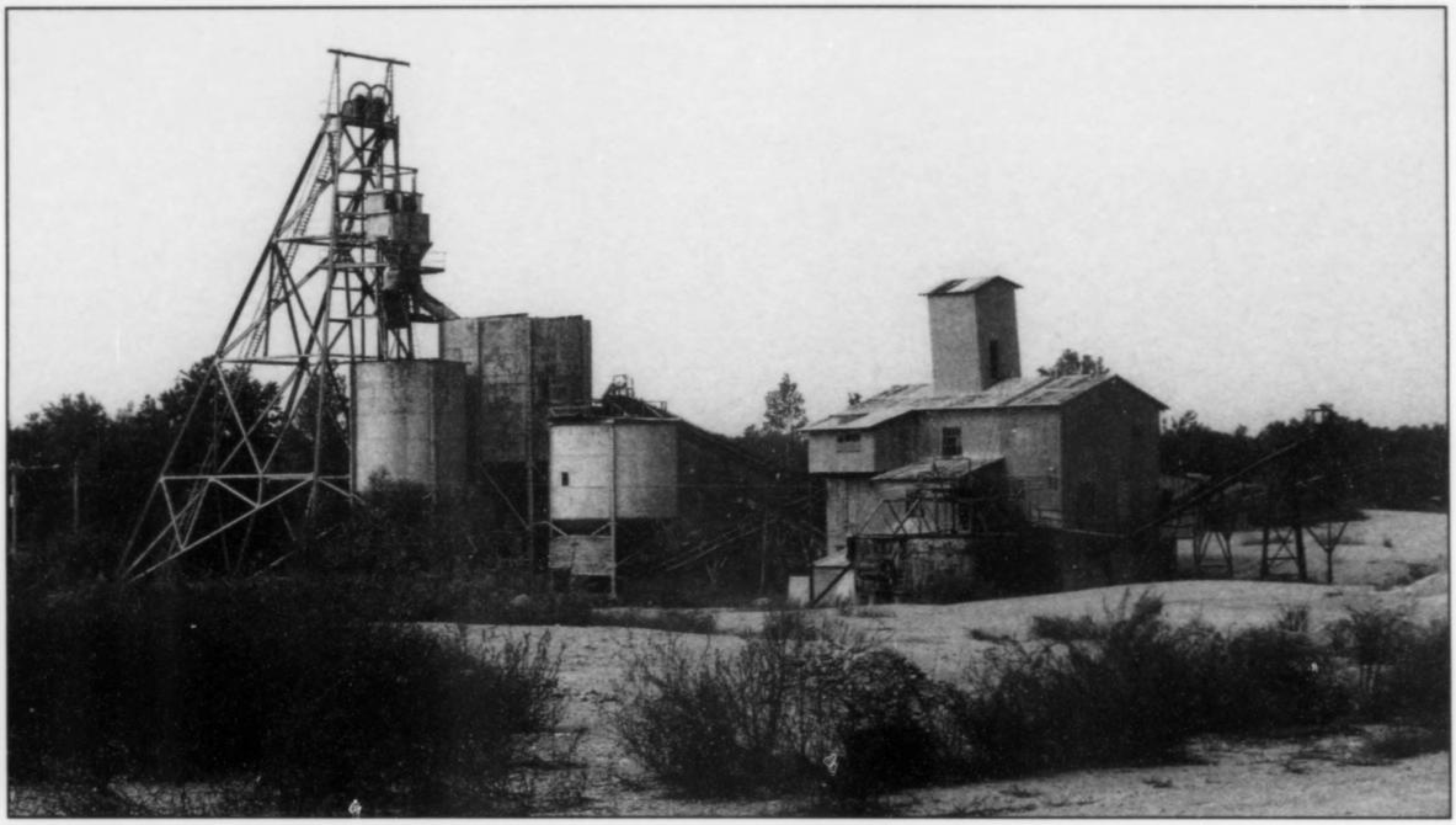


Figure 18. **The Annie L no. 45 shaft and heavy media mill, Spar Mountain. The mill has since been destroyed by fire. Author's photo.**

The town of Rosiclare is still today dominated by the old mill of the Rosiclare Lead and Fluorspar Company, now just a rusting hulk. Earlier in the century it was a hub of activity.

Spar Mountain mines

Spar Mountain is a ridge of Mississippian limestone overlain by a cap of resistant sandstone, located about 3.5 miles northwest of Cave in Rock, Illinois. Prospecting for lead was carried out there for many years prior to the first mining.

Around 1900, the Cleveland-Illinois Fluorspar Company operated a lead mine (also recovering fluorite) at Spar Mountain (Bastin, 1931). In 1919, the Spar Mountain Mining Company of New York mined fluorite there. Fluorite was actively mined by the Benzon Fluorspar Company between 1925 and 1939. The "Benzon mines" consist of the Oxford-West Morrison open cut, the Austin (Lead or Lead Adit) mine, the Cleveland mine, and the Green-Defender mine. With the exception of the open cut, the Spar Mountain deposits are overlain by the sandstone caprock. Ore was generally removed through shallow shafts or adits in the hillside.

Today, the Spar Mountain area remains as the only locality where bedding replacement deposits can be readily seen on the outcrop. Mineral collecting is discouraged because exposures are unstable and dangerous. The present owners have sporadically mined fluorite, but have turned their attentions to products utilizing the Ste. Genevieve limestone and Rosiclare sandstone. The most recent workings were those in the Oxford-West Morrison open cut. The deeply weathered deposits with slumping and confused bedding makes mining difficult, at best. Fluorite specimens up to 40 pounds, with crystals over 3 inches on an edge, were collected during the course of mining operations in 1986.

Yandell mines

The Yandell mines are located on the western part of the Tabb fault system, which has produced the most fluorite in the Kentucky portion of the fluorspar district. The history of the mines here dates back to the 1850's when the first prospect hole was dug for fluorite and galena. Prior to 1873, when Henry Glass shipped fluorite, the Dycusburg Lead Company mined galena there. In 1874, the Cincinnati Fluorspar Company took over mining operations, removing several hundred tons of fluorite. Spar was hauled 5 miles to Dycusburg and shipped by barge from the Cumberland to the Ohio River. In the early 1900's, the Kentucky Fluorspar Company operated the mines. Later, mining operations moved eastward along the fault system.

About 1,100 feet of the Tabb fault system has been mined in the Yandell area. By 1905 there were 24 shafts (the deepest at 115 feet) and three open cut mines. Deeply weathered rock occurs along the vein walls to depths of 85 feet and greater. Vein widths vary from nil to 10 feet, typically 5 feet.

MINING

Prospecting Methods

The first deposits in the district were found by accident. However, it did not take long to determine where to mine. Certain areas carried abundant mineral fragments in the soil, and these "gravel spar" deposits were mined well into the 20th century. Such deposits are formed from the residuum of a fluorite vein at the surface, where at least one vein wall is composed of limestone. Fluorite does not weather away as readily as the surrounding wall rock, accumulating as a concentrate on or near the surface. Intense weathering of bedrock has left "gravel spar" deposits as deep as 250 feet (Thurston and Hardin, 1954).

"Gravel spar" deposits have actually played a role in locating orebodies. The techniques used over the past 80 years are similar to those used in other mining districts. The most common techniques are diamond core drills, churn drills, augers, and (to a lesser extent) test shafts and prospecting pits. Electrical earth self-potential surveys and electric logs have also been used to locate fault zones and orebodies (Weller *et al.*, 1952). Trenches, prospect shafts, tunnels and adits have also been used in seeking orebodies, in vein or bedded deposits. Obviously, these are only useful for near-surface deposits.

Core drilling in areas with the potential for containing orebodies is the most common and economical method used today. It costs less per foot/depth than the other aforementioned techniques. For shallow exploration, auger drills have proven effective because they are fast and easily moved along a fault line. Churn drilling is effective, especially in prospecting for bedding replacement deposits, but is slow (J. Baxter, 1986, personal communication).

The diamond core drill is the most widespread method used during the last 40 years. Cores can reveal, with great accuracy, the location and thickness of a fluorite vein or bedded deposit, as well as the relative displacement of rock strata along fault lines. Multiple coring is essential because vein deposits fluctuate in thickness from greater than 50 feet to less than an inch along the strike of a single fault. Cores have been drilled to depths greater than 1,500 feet, but usually only go to less than 500 feet. Angle holes, 70° to 45° from vertical, are drilled from the surface. The angle chosen depends on the dip of the fault being prospected and the depth to the favorable stratum (J. Baxter, 1986, personal communication). Today, as shallow deposits are worked out, deeper drilling is necessary. The diamond drill has been utilized from within the mine in order to extend underground workings (both horizontal and vertical directions).

Mining Methods

Most of the Illinois-Kentucky fluorite has been produced from underground mines. Surface workings, such as those in the Cave in Rock and Empire districts, are used to exploit smaller deposits or to fully exploit previously worked orebodies.

Detailed descriptions of early mining techniques in this district are scarce. J. T. Worth (1938) describes mining as follows:

> Men at first mined ore very crudely. The mine was a hole in the ground. They reached the bottom by ladders on the side. To keep the sides from caving in on them as they worked, heavy timbers were placed so as to hold these sides perpendicular. Planks were nailed to these timbers to prevent small stones from falling from the sides and hitting the miners below. The ore was hauled up by a bucket which was connected by a rope to a windlass at the top. This arrangement was very similar to that used in wells to raise water. It often took the combined effort of two men to raise the bucket. Holes were driven into the ore by hand steel drills. They were hammered by men who had to twist the drill every time it was hit, so as to crumble the rock and enable them to put powder in. Long fuses were attached and lighted, and the men ran up ladders to safety before the explosion.

Modern mining techniques have involved stoping in vein deposits and room-and-pillar methods in bedded deposits. In vein mining, a vertical shaft is emplaced adjacent to the vein, then a cross-cut tunnel is driven horizontal to the vein. A drift (a horizontal tunnel following the vein) is driven to provide ore, haulage ways and to serve as a starting point for shrinkage stoping and ventilation. The stope is excavated upward by blasting. When a vein is narrow, timbers or bolts are used to support walls as ore is removed. When a vein is too wide, an arch of vein material is left for support. Additional mining levels may be driven above or below the initial level, usually at 100-foot intervals. Ore was hoisted by buckets in earlier days. New safety regulations and good economics required the use of skips (G. Montgomery, 1986, personal communication). Miners are transported in "cages" atop the ore skips.

Minor vein deposits located near the surface have typically been mined by conventional stripping methods. Overburden was removed and the vein was dug out. Often these small deposits were mixed with soil. Ore had to be cleaned in log washers before gravity processing.

Bedded deposits were usually mined by a modified room-and-pillar method. This method is called open stoping. When deposits were found on a hillside, an adit was driven into the hill and room-and-pillar methods were used immediately. Most orebodies were not easily accessible and required a vertical shaft either adjacent to, or directly into the orebody. The shaft was used to haul ore out of the mine (Bradbury *et al.*, 1968). The Crystal mine utilized both shafts and adits to remove ore (G. Montgomery, 1986, personal communication). In most recent times all mining was done through vertical shafts. Small-scale mining in the Spar Mountain area was done with strip mining, removing up to 100 feet of overburden, and also removing old mine pillars.

GEOLOGY

Stratigraphy

The fluorite district is in a region consisting of mostly northeast-faulted sedimentary rocks with scattered narrow mafic intrusions. Sedimentary rocks are from Middle Devonian to Early Pennsylvanian age. In addition to the rock strata, unconsolidated sand, gravel and clay of Cretaceous and Tertiary age as well as loess and alluvium of Quaternary age are present, particularly along the Ohio River and the southwestern part of the district.

The stratigraphic column of southern Illinois is shown in Figure 3. The western Kentucky stratigraphic nomenclature is slightly different, and is illustrated in Figure 4. The productive areas are found in the Meramecian (= Valmeyerian) Middle Mississippian to Chesterian, Late Mississippian-age rocks.

Dikes, Sills and Breccias

About 50 narrow, highly altered mafic and ultramafic dikes and (rarely) sills of Permian age are known in the fluorite district. Several plug-like bodies of breccia have been found punctuating the Illinois Paleozoic rocks, notably on and around Hicks Dome. The dikes have been identified as either mica-peridotites, lamphroites or lamprophyres (Koenig, 1956; Heyl, 1989, personal communication). Most trend northwest, parallel to the axis of the Tolu Arch. With a few exceptions, they are highly altered with serpentine and calcite replacing the original olivine and pyroxene. They contain a holocrystalline, porphyritic and fine-grained to medium-grained groundmass. Minerals occurring in the intrusions are listed in Table 2.

Table 2. **Minerals in dikes (Goldstein, 1982).**

Apatite	Hematite	Pervoskite
Augite	Ilmenite	Phlogopite
Biotite	Leucoxene	Pyrite
Calcite	Limonite	Quartz
Chlorite	Magnetite	Serpentine
Chromite	Muscovite	Sphalerite
Fluorite	Olivine	Titanite
Galena	Orthopyroxene	

The few reported sills in Illinois and Kentucky occur as bedding plane intrusions, generally not far from the parent dike (Koenig, 1956).

The mafic rocks were intruded as a crystalline mush of a moderately low temperature. The temperature of the intrusions was

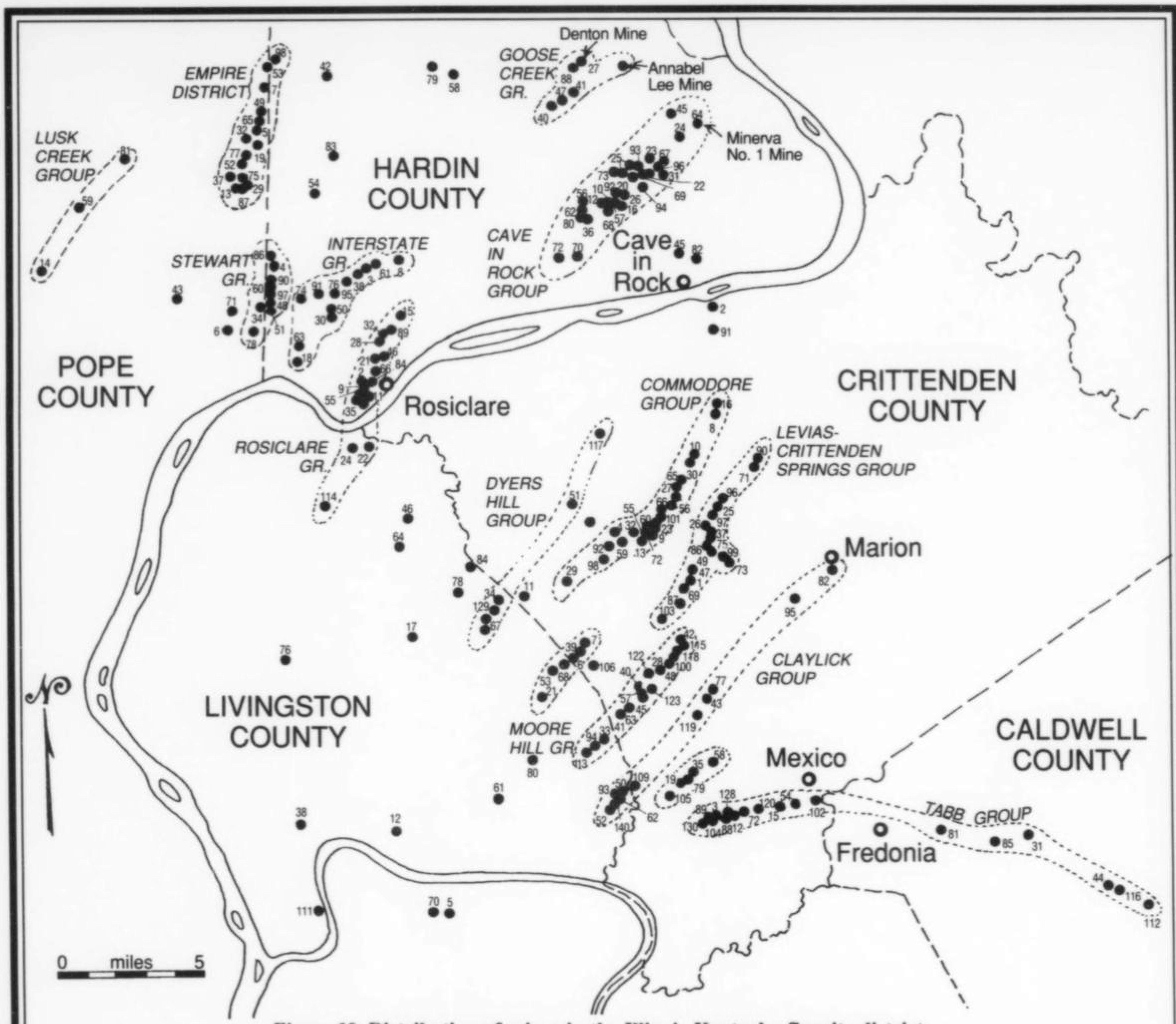


Figure 19. **Distribution of mines in the Illinois-Kentucky fluorite district; numbered mines listed in Tables 3 and 4 (Goldstein, 1987).**

Table 3. **Illinois mines in the fluorite district.**

Addision shaft = *Victory*
Aloca * #
1. Annabel Lee
Annex shaft = *Blue Diggings*
2. Argo shaft
Austin * = Benzon = *Hastie*
3. Austin (near Rosiclare) = Interstate #
4. *Baker* = Eichorn #
5. Baldwin
6. Barnett
7. Beecher Williams
Benzon * = *Hastie* = Austin
8. *Berry* = Sweat
9. Blue Diggings * #
10. Blue Valley shaft = Austin (near Cave in Rock)
11. Buzzards Roost shaft
Carlos shaft = *Victory*
12. Cave in Rock #
13. Churchill shaft
14. Clay Diggings
15. Clement
16. *Cleveland* = Austin = Hastie
17. Cobb
18. Cox
19. Crabb, O.
20. Crystal #
21. Daisy
22. Davis, A. L.
23. *Edgar Davis* = Mahoning
24. Davis-Oxford = *Oxford*
25. W. L. Davis-Deardorff
Deardorff = *W. L. Davis-Deardorff*
26. Defender = *Green-Defender* = Hastie
27. Denton
28. Dimmick
29. Douglas #
30. Dubois #
31. East Green
Eichhorn = *Baker*
32. Empire #
33. Eureka #
Extension shaft = *Blue Diggings*
34. Fairbairn shaft
35. Fairview shaft = Blue Diggings
36. Fluorspar Products
37. Gaskins
38. Gibbons = *K & R*
39. Good Hope
40. Goose Creek
Green = *Green-Defender*
Green Defender = Green + Defender
41. Greene
Grischy*

42. Hamp #
Hastie = Austin = Benzon
43. Henson
Hicks Branch = *Pierce-Hicks Branch*
44. *Hill* = Hill-Ledford
45. Hill (near Cave in Rock)
46. Hillside
47. Hoeb
48. Humm
49. Hutcheson = *Rainey*
50. Indiana
51. Jefferson
K & R = Gibbons
52. Knight
53. *Knox* = Rose Creek
54. Lacey
55. Last Chance shaft
56. Lead Hill #
57. Lead = Austin = Hastie quarry
58. Lee
59. Lost 40
60. Mackey #
Mahoning = *Edgar Davis*
61. Martin #
62. Miller (on Lead Hill)
63. *Miller* = TriState
Minerva *
64. Minerva #1
65. New Baldwin
66. New Ghelia shaft
67. North Green
Oxford = Davis-Oxford
68. Oxford = *Oxford-West Morrison cut* = Hastie
69. Ozark-Mahoning * #, *No. 16 shaft*
70. Palmer
71. Parkinson
72. Patrick (lead)
73. Patton shaft
74. Pell
75. *Pierce* = Pierce- Hicks Branch
76. Preen
Rainey = Hutcheson
Recovery shaft = Rosiclare (too close to other shafts to be shown)
77. Red #
78. Reed shaft = Reid
79. Ridge
80. Robinson
81. Rock Candy Mountain
82. Rodger's = Underwood Property
83. Rose
Rose Creek *
84. Rosiclare * #
85. Shelby
86. Sheldon
87. Slapout #
South Boundry shaft = Rosiclare (too close to other shafts to be shown)
88. Spivey
89. Stewart shaft
90. Stewart #
Sweat = *Berry*
Tri-State = *Miller*
91. Twitchell
Underwood Property = Rodger's
92. Victory #
93. W. L. Davis #2
94. Wall = Hastie
95. Webber Wood
96. West Green
West Morrison = *Oxford West Morrison cut*
97. Williams #
Winn-Underwood = Rodger's

= More than one shaft or pit, may or may not be listed separately
* = Consists of other named mines on the list
Italic = Mine name of most common usage

Table 4. **Kentucky mines in the fluorite district.**

1. Ada Florence #
2. Ainsworth (barite)
3. Asbridge
4. Atlas
5. Atwood
6. Bachelor = Two Bachelors = *Delhi-Babb* #
7. Barnes
8. Beard
9. Bebout
10. Bellman
11. Belt = *Ben Belt*
12. Benard = *Klondike* = Klondyke #
13. Big Four #
14. Billy Owl
15. Blue = *Blue & Marble* #
16. Board
17. Bonanza
18. Bright
19. Brown
20. Butler
21. Butler (near Salem)
22. Carr = Ellis
23. Cartwright
24. Clement
25. *Clement* = Major Clemens
26. Columbia #
27. Commodore #
28. Conyer & Settles Prospect
29. Corn # = Givens?
30. Craighead = *Craighead-Coates*
31. Crook
32. *Crystal* # = Perrigen Springs
33. Cullen = *Cullen-Eagle* = Evening Star
34. Damron
35. Dan Riley = *Riley-Eagle*
36. Davenport #
Delhi-Babb = Two Bachelors = Bachelor #
37. Drescher
38. Dyers Hill
39. Eagle-Babb #
40. *Eagle-Watson* = Liberty Bond= New Watson
41. *Eagle-Wring* = Wring
42. Eaton #
43. Ebbie Hodge = Ebby Hodge
Ellis = Carr
44. Eva Tanguay
Evening Star = *Cullen-Eagle*
45. F. Tyner
46. Ferrall
47. Franklin #
48. Fuller
Givens = Corn?
49. Glass shaft
(56.) Glendale = *Hickory Cane*
50. Goering = Woods
51. Gray
52. Green
53. Guill #
54. Haffaw #
55. Hayshed
56. *Hickory Cane* = Glendale #
57. Hicks
58. Hodge #
59. Holly #
60. Horse Lot
61. Hutson = Hudson # (zinc)
62. Hulet = Pace?
63. J. Tyner
64. *Jameson Prospect* = May
65. Jenkins
66. KK #
67. Kemper #
68. Kentucky-Babb #
69. Keystone #
70. Kibler Hill
71. Klondike, Jr. = Mitchell shaft
72. LaRue #
73. Lady Farmer (zinc)
74. Lafayette #
75. Lanham

76. Lasher-Robinson
77. *Leander White* = White #
Liberty Bond = *Eagle Watson* = New Watson
78. Lola
79. Lovelace = Loveless? (Ulrich & Smith, 1904; Currier, 1923)
80. Loveless = North, South Ramage Prospects? (Trace & Amos, 1984)
81. Lowery (barite)
82. Lucile
83. Macer (not shown, too close to Bebout)
Major Clemens = *Clement*
84. Mann-McDowell (zinc)
85. Marble
86. Mary Belle #
87. Mary Franklin
88. Mary Helen
89. Matthews
May = *Jameson Prospect*
90. Memphis #
91. Mico (barite)
92. Miller
93. Mineral Ridge #
Mitchell shaft = Klondike, Jr.
94. Nancy Hanks #
95. Nannie Bell
96. New Jim
97. Nine Acres
98. Old Dad
99. Old Jim (zinc)
100. Oxley
Pace, John or Luther = Hulet
101. Pasco
Perrigen Springs = *Crystal*
102. Pigmy = Pygmy #
103. Pope
Pope = *Two Brothers* = Watson, H.
104. Pogue shaft
105. Red = Redd
106. Red Fox
107. Reed shaft = Ryan (not shown, too close to Bebout)
108. Riggs shaft (not shown, too close to Bebout)
109. Riley
Riley-Eagle = Dan Riley
110. Roberts & Frazier # (not shown, too close to F. Tyner)
111. *Royal* = Royal Silver
112. Senator-Meadows = *Senator-Black Sulphur* #
113. Shelby
114. Shouse
115. Standard
116. Stone
117. Sullinger = Sullenger
118. Summers
119. Suzie Beeler
120. Tabb * #
121. Tabor #
122. Tightwad
Two Bachelors = Bachelor = *Delhi-Babb*
123. *Two Brothers* = Pope = Watson, H.
124. Tyre = Tyrie
Tyner = F. Tyner or J. Tyner
125. Union (not shown, too close to Klondike, Jr.)
126. Wallace H. Hodge (not shown, too close to Mineral Ridge)
Watson, H. = *Two Brothers* = Pope
127. Wheatcraft (not shown, too close to Tabor)
128. Wheeler
White = *Leander White*
Woods = Goering
129. *Wright* = Professor Wright
Wring = *Eagle-Wring*
130. Yandell #

= More than one shaft or pit, may or may not be listed separately
* = Consists of other named mines on the list
Italic = Mine name of most common usage

about 600° C as determined by the Illinois State Geological Survey (A. V. Heyl, 1989, personal communication). Rocks adjacent to the dikes show slight contact metamorphism. Generally, the effect is not noticeable beyond a foot from the intrusion. The dikes weather to resemble surrounding sedimentary rock and are only visible to the trained eye. The exception is the Claylick dikes in Claylick Creek, Crittenden County, Kentucky, which are continuously washed clean by running water.

Bradbury *et al.* (1955) reported analyses of the Robinson dike, near the apex of Hicks Dome, and the Fowler dike near Salem, Kentucky. The former contains anomalous concentrations of rare earths, niobium, zirconium and beryllium.

The breccias (diatremes) and breccia "dikes" in Illinois have been discussed by Baxter and Desborough (1965), Baxter *et al.* (1967), Brown *et al.* (1954), and Clegg and Bradbury (1956). Baxter and Desborough (1965) described the breccias as consisting of:

> Angular to subrounded fragments of sedimentary, metamorphosed sedimentary, and igneous rocks in a matrix of finely ground rock (from wall rock) and mineral fragments. The mineral fragments include quartz, pyroxene, augite, [nepheline] hornblende, apatite, mica [phlogopite or magnesian biotite], and feldspar.

Seven breccia plugs are known, up to 1,000 feet in diameter. They are circular or oval in plan, but the true geometric shape is unknown.

Trace (1960) analyzed a breccia on Hicks Dome which is radioactive. It was found to contain monazite (later reidentified as brockite) and florencite in subordinate amounts. Brockite was found to occur as small (0.1–0.2 mm), soft, earthy, round, brownish yellow grains.

The unusual mineralization was reported, both on the surface and at depths exceeding 2,000 feet, in the breccias at Hicks Dome. Various authors including Brown *et al.* (1954), Bradbury (1962), Hall and Heyl (1968), Heyl *et al.* (1965) and Trace (1960), reported thorium-bearing and rare-earth-bearing fluorite with sphalerite, galena, barite, monazite (later found to be brockite), florencite, bertrandite, calcite, quartz, pyrite, brookite, yttroparisite (?), biotite, rutile, xenotime and apatite.

Structure

The Illinois-Kentucky fluorspar district is located in the most complexly faulted area of the central United States. The district occurs where the 38th Parallel Lineament—a series of fault zones extending from Virginia to Missouri—intersects the New Madrid fault zone. The latter is the most active fault zone in the United States east of the Rocky Mountains. It was responsible for the three great earthquakes of 1811–1812, estimated to be greater than 8.0 on the Richter scale. The origin of the 38th Parallel Lineament is unknown. It is a high-angle zone extending deep into the Precambrian (as determined by gravity and magnetic studies; A. V. Heyl, 1989, personal communication). The New Madrid fault zone is thought to be an *aulacogen*—the failed arm of a plate tectonic rift system. The age of rifting was Precambrian, so the history of the fluorite district, indirectly at least, goes back over 700 million years.

Fluorite is found in other areas along the 38th Parallel Lineament. The central Kentucky fluorite district occurs where the Lineament intersects the crest of a broad fold structure called the

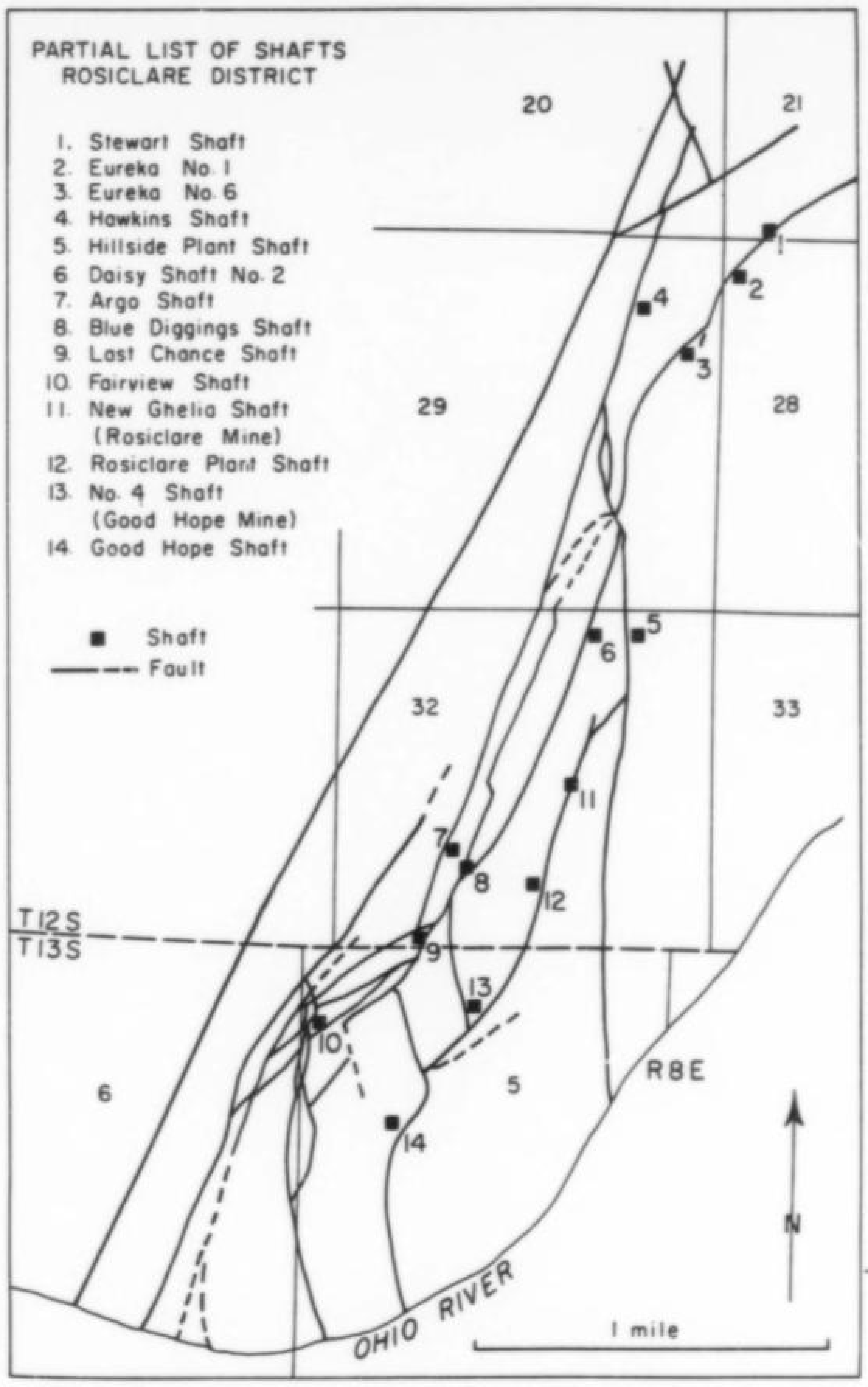


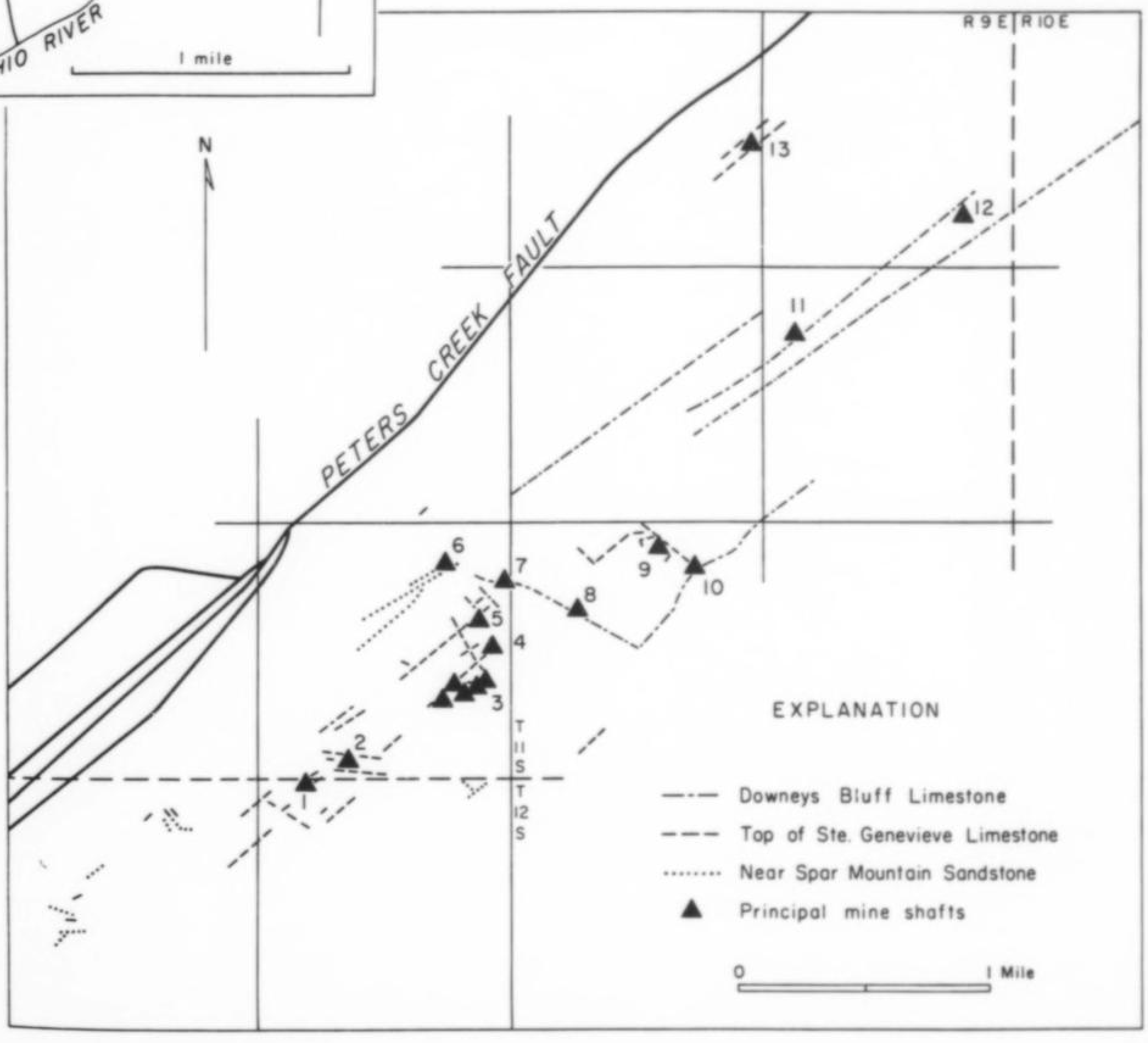
Figure 20. **Faults and mine locations, Rosiclare area (Grogen and Bradbury, 1968).**

Cincinnati Arch. Fluorite can be found in minor amounts at various limestone quarries through Kentucky, especially in the Mississippian strata.

Located near the intersection between the two major fault zones is a cryptoexplosive structure known as Hicks Dome. This dome is not a laccolith, but rather a large breccia "hill" overlain by an 11,000 to 15,000-foot-thick sequence of sedimentary rocks. The presence of radial and arcuate faults, as well as breccia plugs (described earlier) indicate that Hicks Dome postdates the Paleozoic rocks in the region. The Middle Devonian strata exposed in the center of the dome are found at a depth of 4,000 feet only a few miles away.

The southeastern section of the dome has been truncated by a 4 to 5-mile-long down-dropped block called the Rock Creek Graben. Southward, across the Ohio River in Kentucky, is an extension of a structural high known as the Tolu Arch. The general structural contours in Kentucky reflect a complicated series of horsts and grabens, bounded on the south by the Tabb fault system (Rogers and Hays, 1967).

Figure 21. **Principal deposits and mineralized trends, Cave in Rock area (modified from Grogan, 1949). 1. Addison shaft, Victory mine. 2. Carlos shaft, Victory mine. 3. Crystal mine shafts, nos. 1, 2, 5, 6, 7. 4. Crystal shaft no. 3. 5. Crystal shaft no. 4. 6. Davis-Deardorff mine. 7. W. L. Davis no. 2 mine. 8. A. L. Davis mine. 9. West Green mine, 10. East Green mine. 11. Oxford mine. 12. Minerva No. 1 mine. 13. Hill-Ledford mine.**



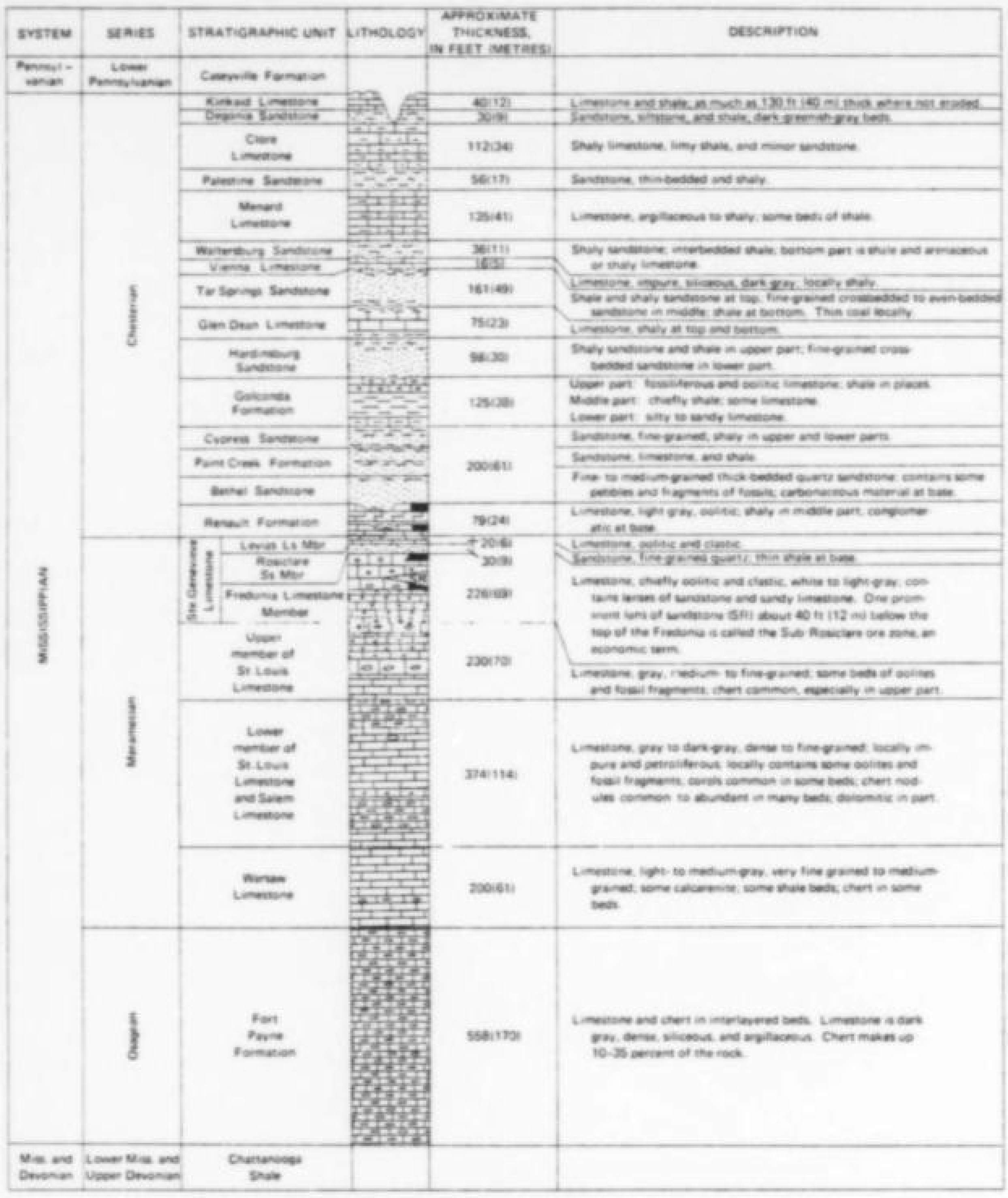


***Figure 22*. Mississippian formations in the Illinois-Kentucky fluorite district (Pinckney, 1976).**

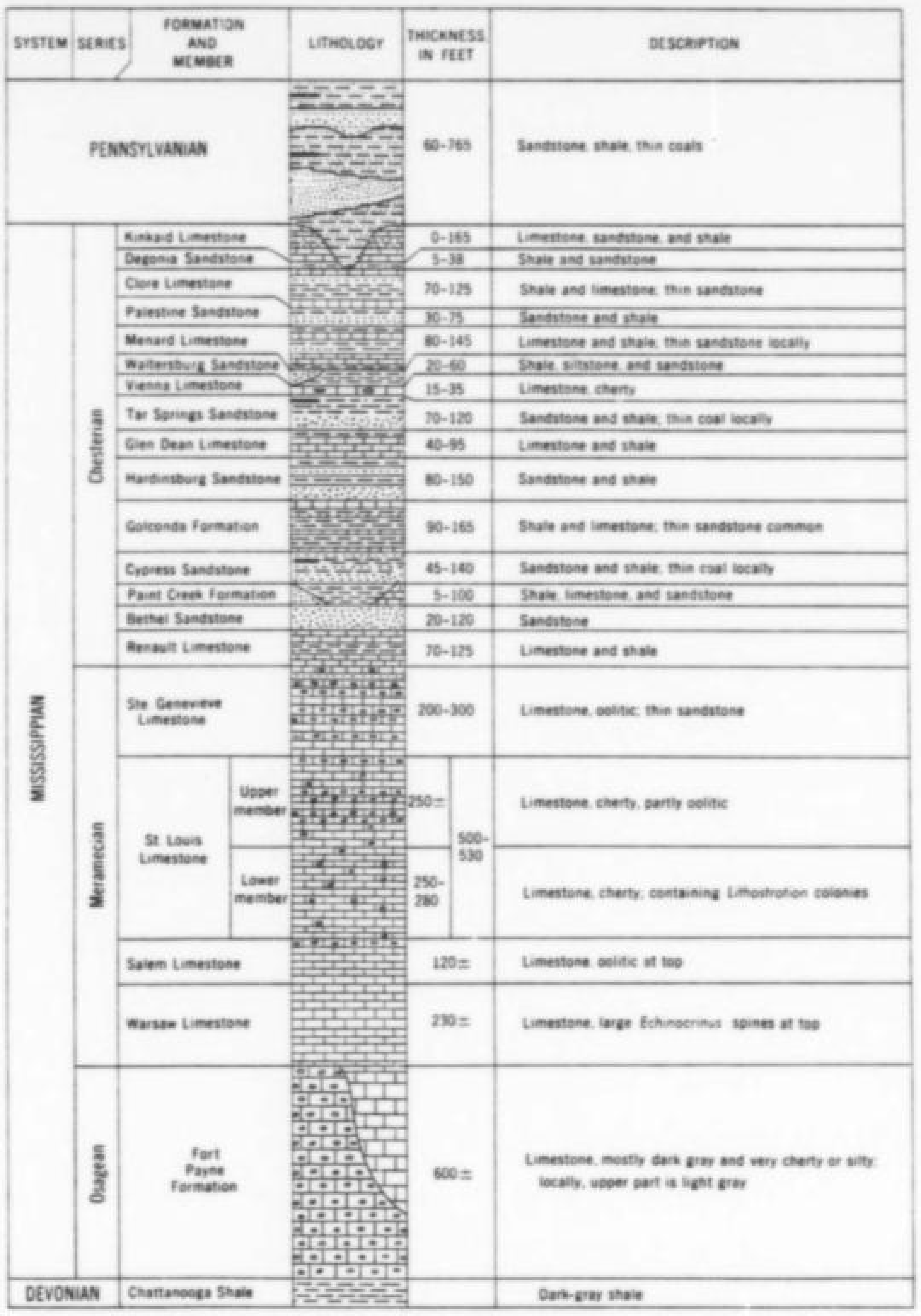


***Figure 23*. Generalized stratigraphic column of formations exposed in the western Kentucky portion of the Illinois-Kentucky fluorite district (Trace, 1974b).**

The faults occurring in the district are largely steeply dipping to vertical, with inclinations rarely as low as 45°. Faults are of the normal variety, though the dip of an individual fault and vein may be locally reversed (Hardin, 1955). Along the edges of many of the larger grabens, fault zones consist of several subparallel and sinuously intersecting fractures (Trace, 1966). These zones can be more than 1,000 feet wide.

Evidence of vertical displacement as much as 3,000 feet has been found in the southwest corner of the Burma quadrangle, where Pennsylvanian rocks are abutting Early Mississippian cherty limestone (Trace, 1974a, b). Generally the displacement is between a few feet and a few hundred feet.

Deep core drilling has been very sparse, so the displacement of strata below 2,000 feet is, for the most part, unknown. A few 2,000-foot holes indicate displacements similar to that at the surface.

Horizontal fault displacement has not been extensively studied. Weller and Sutton (1951) indicate that at least some horizontal motion has occurred. Clark and Royds (1948), Heyl and Brock (1961), and Heyl (1972) all suggest that substantial horizontal motion may have occurred. The strike-slip component is not widely published, but is readily apparent to company geologists who spend considerable amounts of time underground (A. V. Heyl, 1989, personal communication).

Geologic History

Although there is no consensus of opinion among geologists, a possible sequence of events leading to the current state of the district has been tentatively developed. The exact timing of individual events and the peculiar geologic features are still being debated. Repetition of both structural and mineralogical events has occurred, confusing the situation. The time interval of these events has been determined to be from Late Pennsylvanian to possibly Late Cretaceous—a span of 200 million years! First came the structural uplift forming the Tolu Arch. The intrusion of mafic dikes and sills may have occurred at this time, as most of them strike parallel to the axis of this arch (A. V. Heyl, 1989, personal communication). Hicks Dome might have formed much later (J. Baxter, 1986, personal communication). Zartman *et al.* (1967) have radiometrically determined the dikes to be Early Permian age. The Elliott County, Kentucky, peridotite/kimberlites (about 250 miles east) are of similar age. Next came the movement of the northeast-trending faults. Mineral deposition appears to have occurred after the faulting, though fluorite showing slickensides indicates post-mineralization movement of rock. Fluorite appears to have been deposited in post–Middle Pennsylvanian and pre–Late Cretaceous time. Heyl (1982) indicates that mineralization took place primarily in the late Paleozoic or early Mesozoic, with supergene mineralization occurring in the Cenozoic.

Most mineralogists consider the deposits to be epigenetic, the elements in the ore being carried by hot connate water heated by igneous activity. Some of the minerals may have been deposited by connate brines (Hall and Friedman, 1963).

Heyl *et al.* (1966) offer a hypothesis for the mineralization in the district using lead isotopes and zonal patterns. All galenas of the district are of the "J" type, being relatively enriched in radiogenic isotopes as compared with ordinary lead. They note that the ratios of Pb206/Pb204 and Pb207/Pb204 show a general rise in values away from Hicks Dome. Pb208/Pb204 also shows this trend, except at Hicks Dome itself (due to Pb208 contamination, since thorium is abnormally high in the intrusive breccia found there).

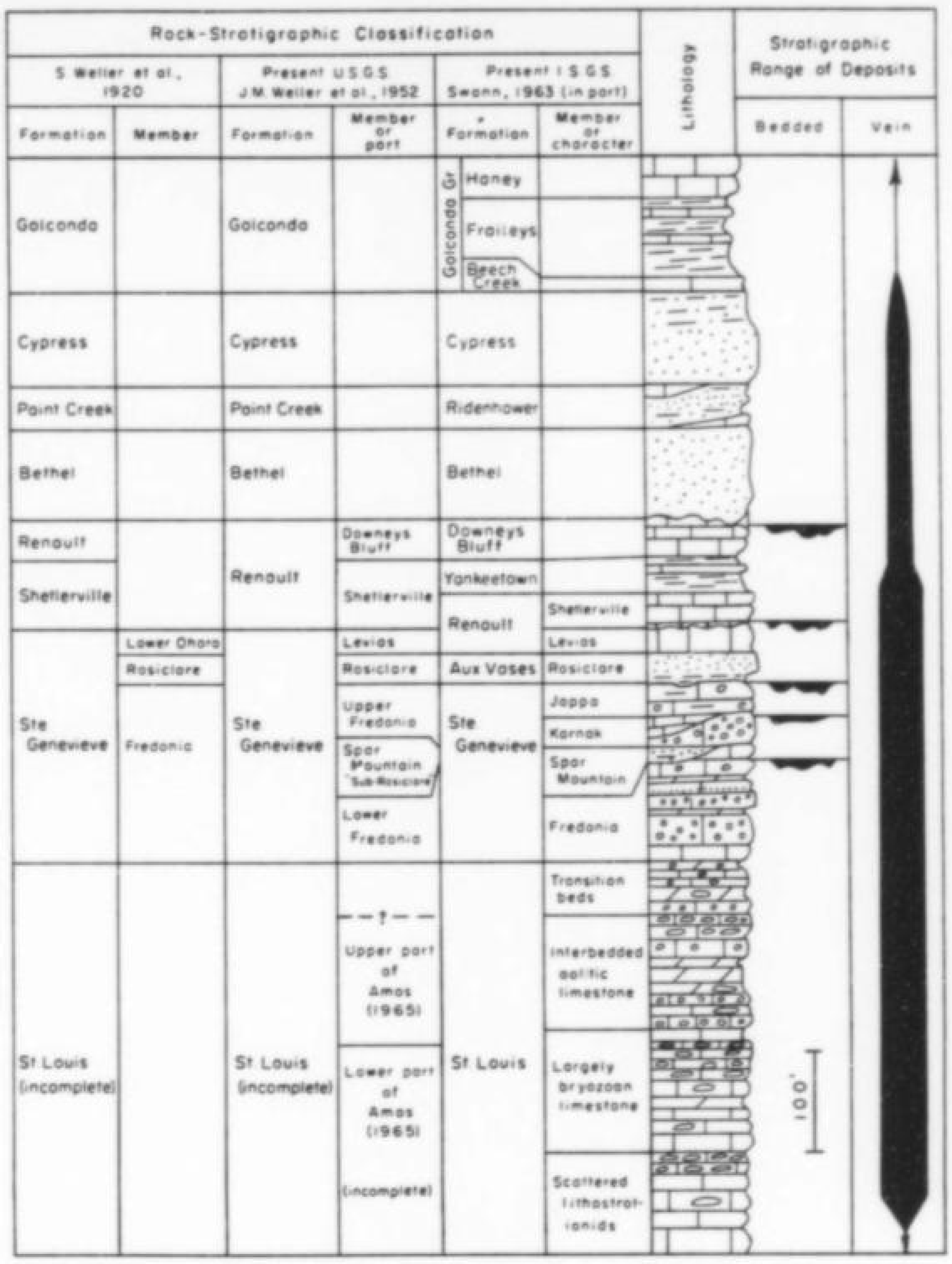


Figure 24. **Lower Chesterian and upper Valmeyeran strata in the Illinois-Kentucky fluorite district, showing the stratigraphic range of vein-type and bedding-replacement deposits (Baxter *et al.*, 1973).**

Additional evidence includes the amount of silver found in galena. The amount tends to decrease in a southeasterly direction from Hicks Dome. Barite tends to be abundant toward the margins of the district. No zonation is apparent in either fluorite or sulfides, although there appears to be a relationship between vein deposits of sphalerite and mafic dikes (e.g. Old Jim, Hickory Cane, and Hutson mines).

In the stratiform deposits near Cave in Rock, the apparent origin of the mineralization can be stated in the following hypothesis (Grogan and Bradbury, 1967): fluorine was emplaced by convection of connate water driven by heat of magmatic origin. The bedding replacement deposits were emplaced as mineralizing fluids entered a network of fractures, rising to where host rock characteristics, hydrologic and other factors combined to favor precipitation of these deposits.

Fluorite deposited by connate water was corroded by a pulse of magmatic water of different chemistry (of the same temperature) which deposited quartz, sphalerite and galena. Changes in internal flow patterns then caused a decrease in magmatic water and an increase in connate water with fluorite, much like the original pulse. Conditions changed so that meteoric waters then deposited sulfate and carbonate minerals.

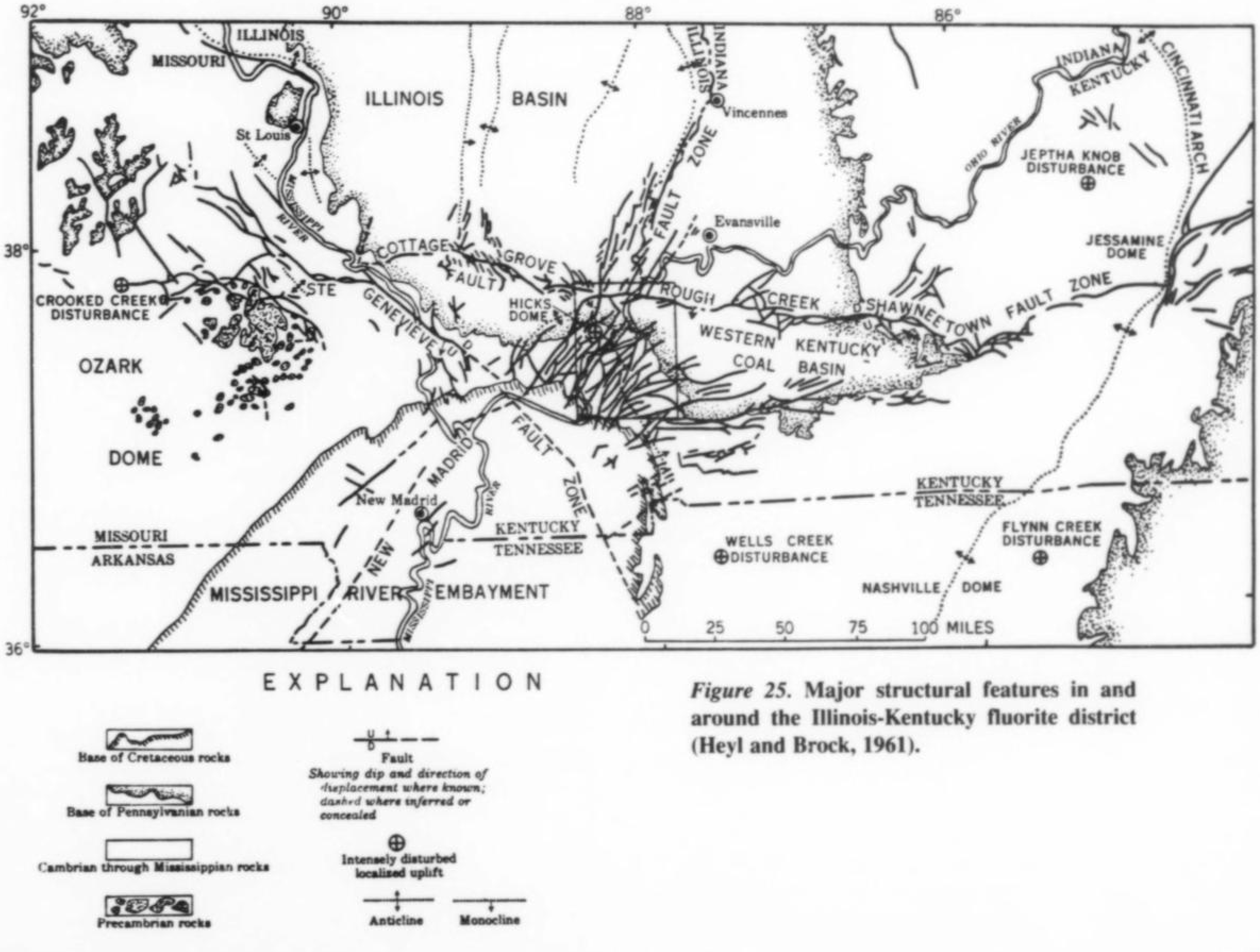


Figure 25. **Major structural features in and around the Illinois-Kentucky fluorite district (Heyl and Brock, 1961).**

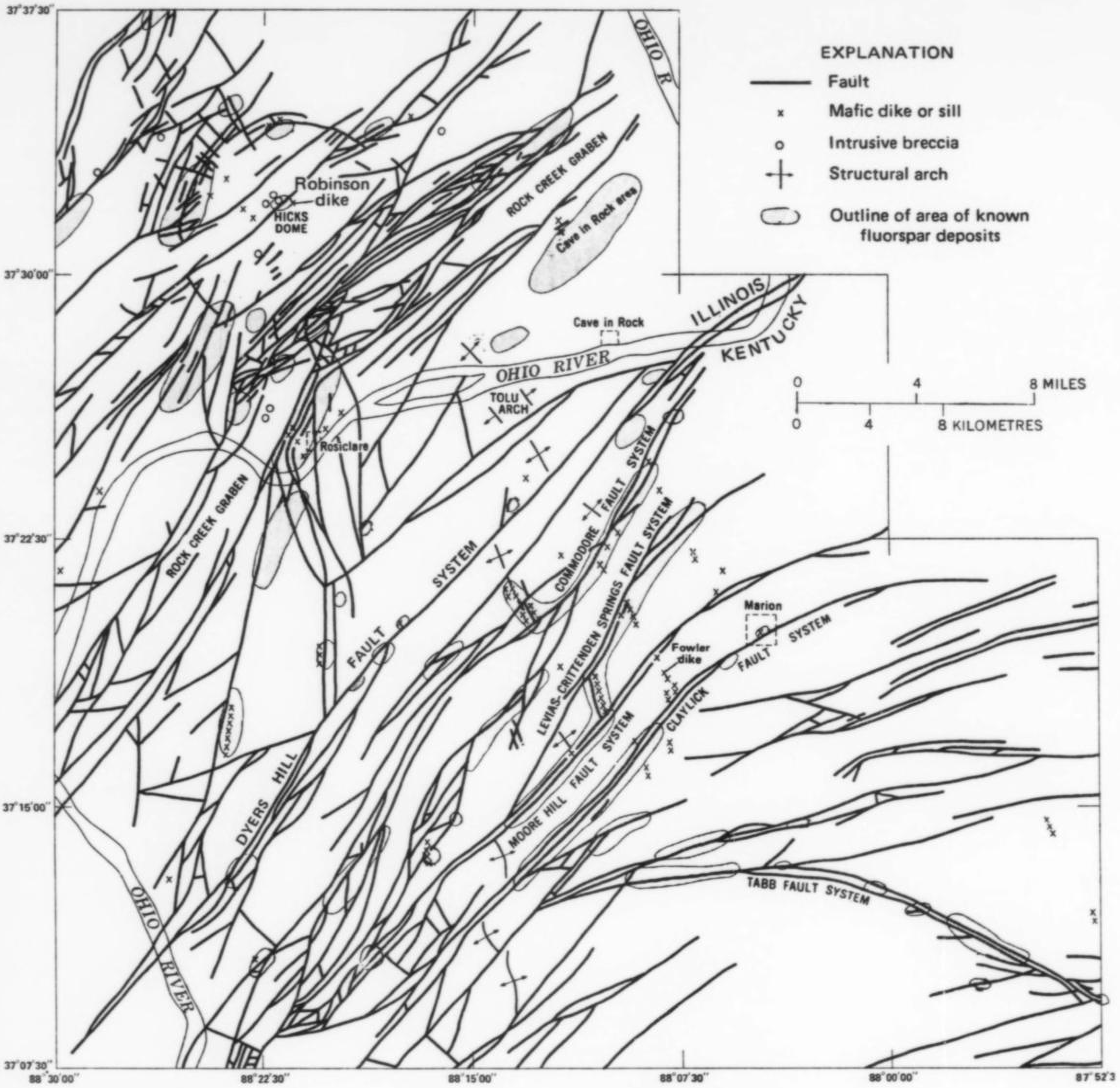


Figure 26. **Major structural features relative to known fluorite deposits in the Illinois-Kentucky fluorite district (Shawe, 1976).**

Others (Amstutz and Park, 1967) consider the origin to be syngenetic, with ore being derived from the sedimentary rocks, without depending on igneous activity. However, A. V. Heyl (1989, personal communication) believes that most of the fluorite in the district occurs in large veins that cannot be ascribed to syngenetic origin.

Paragenesis

Detailed studies of mineral paragenesis have been carried out in the Cave in Rock bedding replacement deposits by various writers including Hall and Friedman (1963), Heyl (1982), and Richardson and Pinckney (1984). All but Heyl obtained their information from studying the deposits at the Davis-Deardorff, Hill and Oxford mines. Heyl's work was from a district-wide study.

The earliest mineral to form was rhombohedral calcite, which was deposited after the solution of the limestone host rock. It occurs as veins and crusts between wall rock and fluorite, although most of it was replaced by later minerals (R. D. Trace, personal communication). Some rhombohedrons are intimately associated with yellow fluorite, the first of five major fluorite sequences. Richardson and Pinckney (1984) list nine fluorite sequences (see below). In addition, they consider early rhombohedral calcite to be intergrown scalenohedrons with prominent cleavage planes. (The writer has found crystalline rhombohedral calcite on the dumps at the Rosiclare Lead and Spar Company mill site.) Scalenohedral calcite does not occur until late in the paragenetic sequence.

The earliest fluorite is unquestionably yellow. Most mines studied show yellow fluorite being deposited before any other color. Exceptions occur, but can be explained by the lack of an opening into that particular area in the deposit when solutions were precipitating yellow fluorite.

Yellow is followed by a thin purple zone. Hall and Friedman

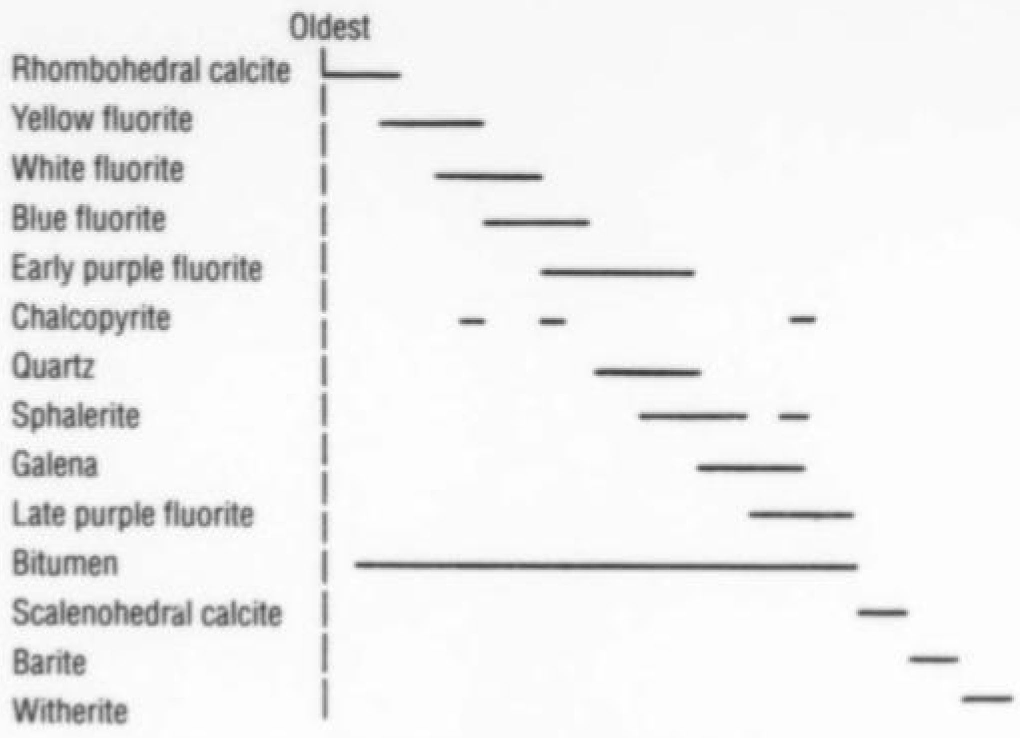


Figure 27. **Paragenetic sequence in the Cave in Rock area, Illinois (Brecke, 1964a).**

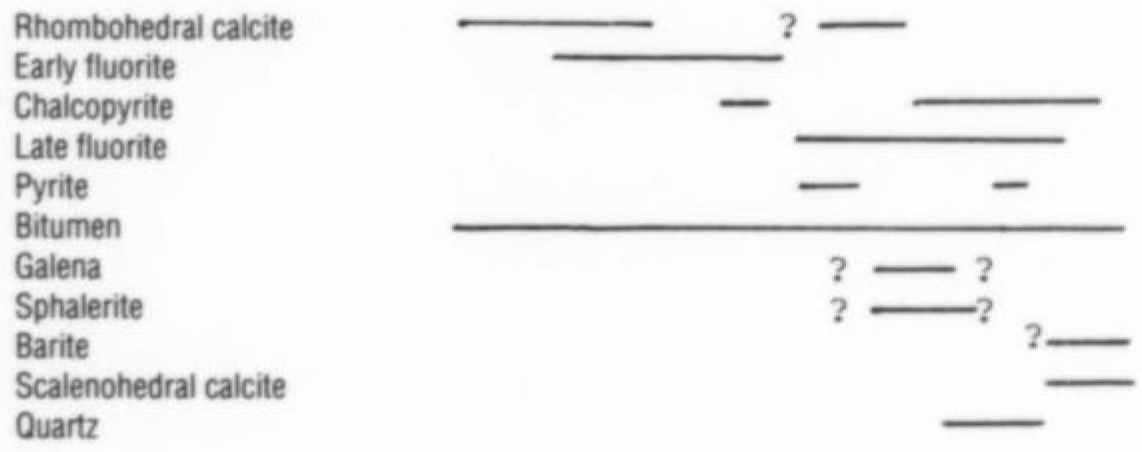


Figure 28. **Paragenetic sequence in the Rosiclare area, Illinois (compiled from Bastin, 1931).**

(1963) describe white and blue following the thin purple fluorite. Richardson and Pinckney (1984) describe a second deposition of yellow fluorite which lacks carbonate inclusions. It also contains chalcopyrite near the contact with the next color zone, and may locally contain quartz inclusions. The contact between the next zone is frequently very porous, almost spongy, with fluid inclusions.

The second purple fluorite zone ("P2") of Richardson and Pinckney (1984) equals the white and blue fluorite of Hall and Friedman (1963). They describe this zone as being pale blue, bluish purple, or pale purple. It may occur within the ragged zone of the second yellow fluorite. They consider the white to be a pale part of the "P2" zone. The "P2" zone may contain inclusions of sulfides, quartz and bitumen. Later zones of purple fluorite grew expitaxially on earlier fluorite and show multiple zoning.

There is substantial overlap of zoning throughout the district. Richardson and Pinckney (1984) described five more purple zones (totaling seven purple) interspersed with colorless bands. They describe the white zones as occurring between two purple zones (i.e. white zone between "P5" and "P6"). This is Hall and Friedman's late purple stage.

Hall and Friedman (1963) found three stages of chalcopyrite deposition. The first within yellow fluorite ("Y2" of Richardson and Pinckney, 1984), the second within white/blue/early purple ("P2" as above), and the third following most quartz, sphalerite and galena (later purple fluorite is also included).

Bitumen is found to be present continuously from the yellow through late purple stages. Petroleum zonation is very distinct in crystals when examined with an ultraviolet lamp. Black masses of bitumen commonly coat fluorite and sphalerite.

Hall and Friedman (1963) and Richardson and Pinckney (1984) give contradictory information about the later mineral paragenesis. The earlier writers found overwhelming evidence that the deposition of quartz, sphalerite, galena and late fluorite occurred under conditions oscillating near equilibrium (between precipitation and solution) over a long period of time. They noted that delicate zoning observed in crystals often shows evidence of leaching at the zonal boundaries. Richardson and Pinckney (1984) noted sharp boundaries with solid inclusions crossing zonal borders, with little evidence of dissolution during quartz and sulfide deposition!

The paragenesis of the vein deposits in the fluorite districts has not been studied in the same detail as the bedding replacement deposits. Figure 10 is a simplified diagram based on four diagrams in Bastin (1931) from the Rosiclare and Hillside veins. Overall, it is very similar to Hall and Friedman's diagram. Early work was done by studying specimens from the mine dumps and, to a lesser extent, detailed examinations from within the mine.

Orebodies

The deposits of fluorite occur in three forms: veins, bedding replacements, and breccia pipes. Vein deposits are vertical or near vertical, while bedding replacement deposits are horizontal or slightly dipping. Ore-bearing breccia pipes occur at low places in the bedded orebodies along controlling faults. They were not mined at depth because company engineers did not know how to do so (A. V. Heyl, 1989, personal communication). All are fault-related, the latter less conspicuously.

The **vein deposits** are the most widespread in the district. Most veins are found in predominant northeast-trending faults. Veins are of variable thickness, pinching and swelling erratically. Typical vein thicknesses are between 3 and 10 feet, occasionally swelling to as much as 40 feet. Ore shoots may be in excess of 400 feet long and 200 feet high. The fluorite veins most frequently occur as fissure fillings along faults. Occurrences in fault breccias and replacement of vein calcite and wall rock are common. A few have small bedding replacement deposits extending out from the feeding fault veins (A. V. Heyl, 1989, personal communication).

Trace (1974a) notes that "fluorite varies from fine and medium crystalline in small, commonly purple, veinlets to coarsely crystalline in commonly brown, white or colorless, more massive veins." Veins are commonly brecciated and/or sheeted. Locally, rough banding occurs parallel to vein walls. It is not unusual to find bits of carbonaceous shale in vein deposits. Material from the 1,000-foot deep Henson mine shows this shale gouge. The shale is undoubtedly derived from Chester-age strata.

The **bedding replacement deposits** are located in the vicinity of Cave in Rock, Illinois, in the northeastern part of the fluorite district. Other deposits are located near Joy, Kentucky, across the river from Rosiclare. Deposits follow minor faults and fractures that trend in a northeast direction. Both run parallel to long grabens. Substantially continuous deposits of approximately 20,000 feet in length are known, although most are much smaller. Widths of the deposits are typically 50 to 200 feet, and 5 to 20 feet thick (Grogan and Bradbury, 1967).

Certain rock strata are prone to bedding replacement. Major replacement deposits occur in the Downeys Bluff Limestone (lower Chester age) which is overlain by the Bethel Sandstone (often called the "sub-Bethel"), the Joppa member of the Ste. Genevieve Limestone which is overlain by the Rosiclare Sandstone (often called the "sub-Rosiclare"), and the Spar Mountain member of the Ste. Genevieve Limestone, overlain by the Karnak member. The overlying strata generally have an impermeable shale layer at their base. Minor bedding replacement occurs in the Levias member of the Renault Formation and the Karnak member of the

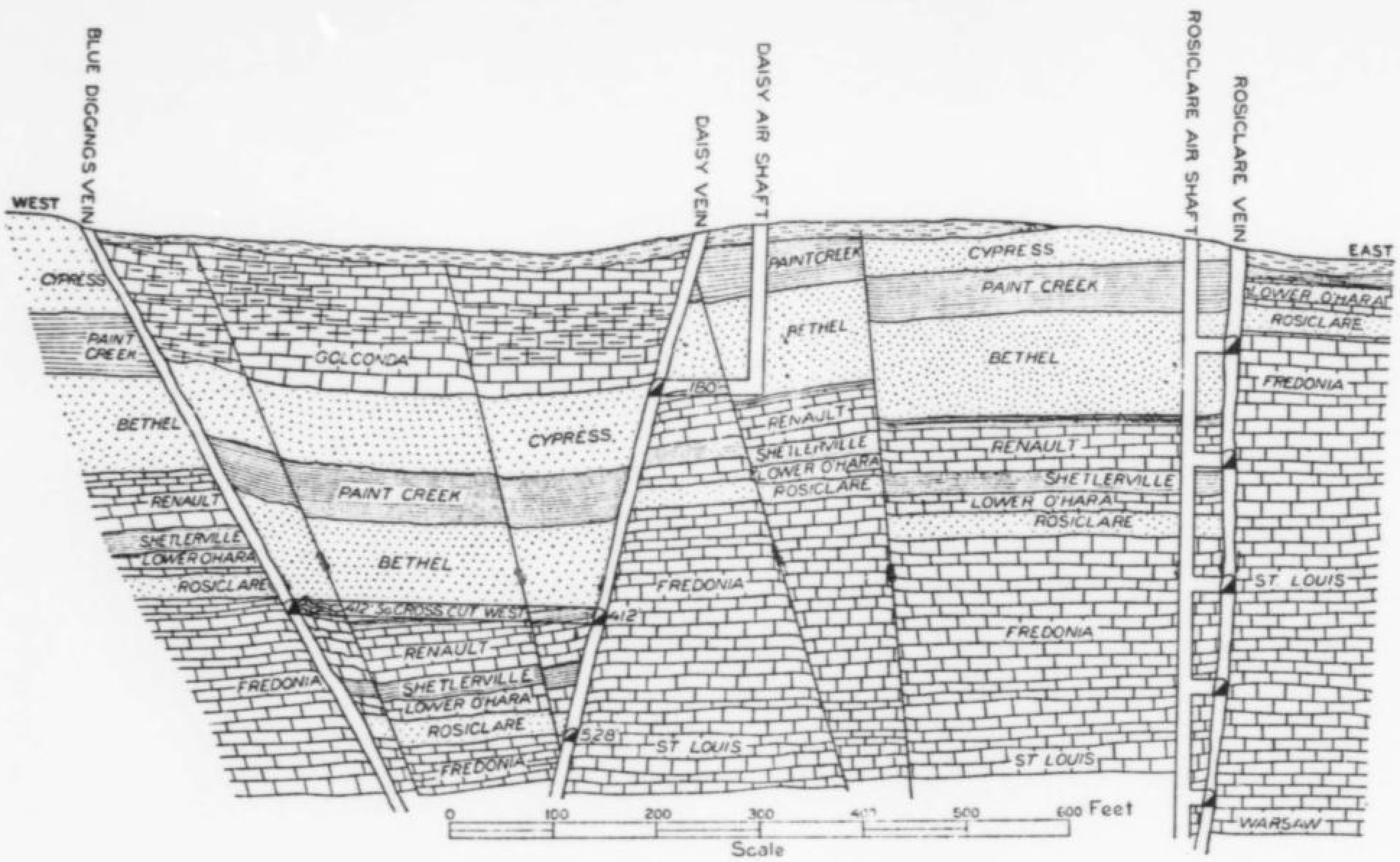


Figure 29. **Cross-section through the Blue Diggings, Daisy and Rosiclare veins (Bastin, 1931).**

Ste. Genevieve, beneath localized shale occurrences. The underlying St. Louis Limestone does not have shale seams in known positions as does the Ste. Genevieve Limestone. Fluorite occurrences in this formation are widely scattered.

The shales acted as dams for rising mineralizing solutions. With a shale cap rock, solutions spread out laterally from the feeding faults and fractures, forming crescentic or wedge-shaped deposits (Grogan, 1949; Brecke, 1962). Eric Livingston (personal communication, 1996) reported seeing several 100 to 150-foot diameter collapse features in the Denton mine and several similar but less distinct structures in the Annabel Lee mine. The limestone was replaced by fluorite at the time of deposition. Scattered solution-collapse features indicate that localized caving occurred. Selective replacement of crystalline calcite occurred along the periphery of deposits and in the Rosiclare Sandstone. Curious fluorite-replaced fossils can be found at these points, although perfect preservation is uncommon. Bastin (1931) notes fossil echinoderms wholly or partially replaced by fluorite. The writer's collection includes well-preserved solitary and colonial corals, crinoid columns and calices, bryozoans, and blastoids, including a rare *Diploblastus* wholly or partially replaced by fluorite.

In several bedding replacement deposits, large breccia pipes were found. Brecke (1962) describes two such pipes about 250 feet in diameter and in excess of 500 feet in vertical dimension. The total depth of mineralization is unknown. Strata had slumped as much as 100 feet. The mineralized zone of the breccia pipe of the North Green mine spanned the St. Louis Limestone to the Cypress Sandstone (Brecke, 1982). No alteration of wall rock was noted beneath the contact collapse zones. No effort was made to locate the lower limit of mineralization in that pipe. Arguments over whether these breccia pipes represent the source of fluorite activity have met with no general agreement. They undoubtedly represent areas of high solution activity. Brecke (1982) and Heyl (1989, personal communication) consider these pipes to be primary conduits of ore solutions for the bedding replacement deposits. The ore-forming fluid removed a greater volume of rock than was replaced by fluorite, causing the development of open cavities and sagging beds (Grogan and Bradbury, 1967).

Bedding replacement deposits are noted for their "coon-tail" ore, consisting of rhythmic banding of fluorite (as evidenced by multiple colors) or other minerals. Grogan and Bradbury (1967) indicate that these ores were formed in "backwater" areas where conditions were quiescent. High-grade coon-tail ore is nearly impossible to find in worked mines. On the periphery of the ore deposits, low-grade coon-tail ore consisting of alternating bands of fluorite/barite or fluorite/limestone may be found. Fluorite/sphalerite and sphalerite/quartz have been reported in the Deardorff mine (Brecke, 1982). The Lead Hill and Cave in Rock mines both reported banded fluorite/quartz (Weller *et al.*, 1952).

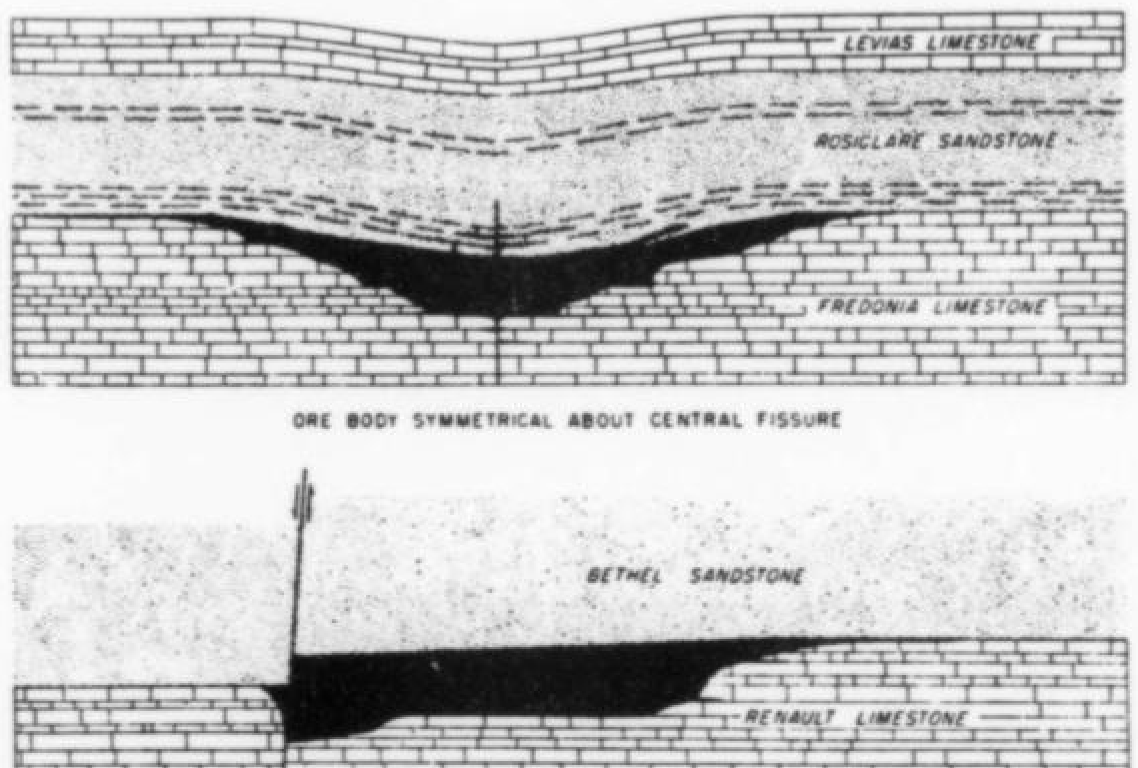


Figure 30. **Characteristic cross-sections through stratiform deposits in the Illinois-Kentucky fluorite district (Grogan, 1949).**

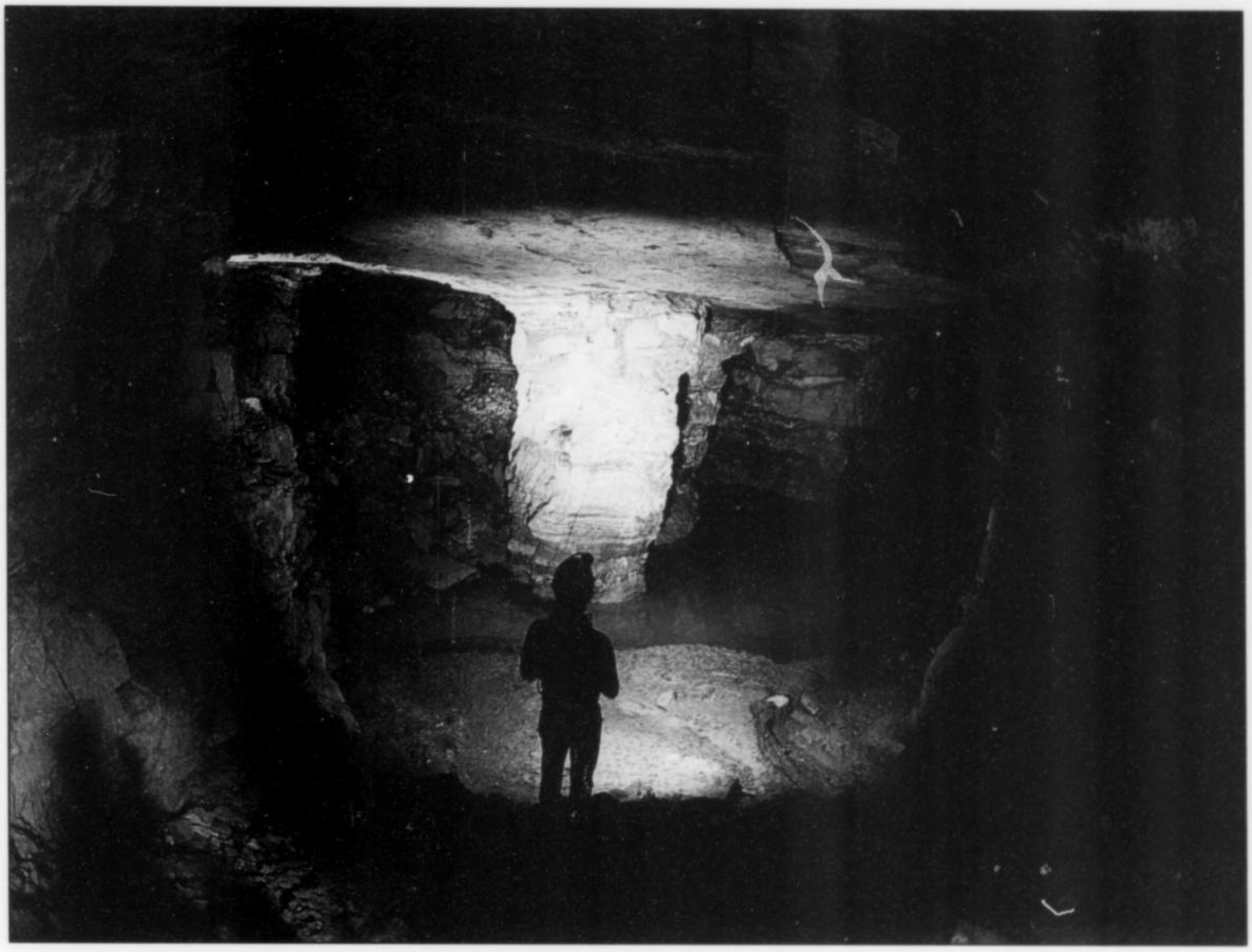


***Figure 31.* Room and pillar mining at the Victory mine, typical of the way bedding-replacement deposits near Cave in Rock were mined. Chris Anderson photo.**

MINERALOGY

The vein and bedding replacement deposits contain virtually the same minerals. Calcite is more abundant in vein deposits, though not insignificant in bedding replacement deposits. Brecke (1964a) found concentrations of barite in areas most remote from the source of solution. Barite occurs on the periphery of single orebodies, around centers of mineralization, and throughout the district as a whole.

Sulfides occur throughout the district and have been economically significant in several orebodies. Zinc in the form of sphalerite (and, to a lesser extent, smithsonite) has been found in economic deposits in both Illinois and Kentucky. In several of the Cave in Rock district bedded deposits, the zinc mineralization was essential to the economics of various orebodies. The sale of zinc concentrates was often more rewarding than the sale of fluorite (G. Montgomery, 1986, personal communication). Heyl (1989, personal communication) considered this area as one of the most important zinc-producing areas in the United States. The value of lead was less important.

This was especially true of the large orebody at the Minerva No. 1 mine, north of Cave in Rock, where most of the production came from the replacement of the Renault Limestone. In the northeast ends of the parallel ore leads, zinc was important in three levels of the Fredonia member of the Ste. Genevieve Limestone (G. Montgomery, 1986, personal communication). Sphalerite containing germanium was a major ore in the Deardorff mine, and the *only* ore in the Hutson mine across the river in Kentucky.

Galena has not been found in exclusive deposits, although it was abundant at the Patrick lead mine west of Cave in Rock, where the ore was sold for lead-silver concentrate (Heyl, 1989, personal communication). All other sulfides, sulfates and carbonates (excluding calcite and barite) occur in minor amounts and are of little or no economic value except to the specimen collector.

Hall and Heyl (1968) report the fluorite in the district to be remarkably free of impurities, except for that found around Hicks Dome, which contains thorium and rare-earth elements. The green fluorite contains trace amounts of yttrium. This may account for the bright blue fluorescence of the fluorite found around Hicks Dome, whereas the fluorite (excluding petroleum inclusions) in other areas of the district is not fluorescent.

The following species have been reported in the literature from deposits in the fluorite district, or have been found on hand specimens. Detailed analytical work has generally not been carried out, but most species are easily identified megascopically.

Alstonite $CaBa(CO_3)_2$

Alstonite is a rare mineral which has been reported from the Minerva No. 1 mine as very small (ca.1 mm) sharp, white, pseudohexagonal dipyramids associated with benstonite, calcite and witherite. This is the only known North American occurrence of alstonite.

Anglesite $PbSO_4$

Anglesite is very rare in the fluorite district, occurring as a weathering product of galena. Only one locality has been reported in the literature, the Patrick lead mine (Weller *et al.*, 1952). However, there are several other localities where anglesite may be found, including Conn's mine in the Empire district, the W. L. Davis-Deardorff and Minerva No. 1 mines in the Cave in Rock district, and the Columbia, Hickory Cane and Hutson mines in Kentucky.

Ankerite $Ca(Fe,Mg,Mn)(CO_3)_2$

Ankerite has been reported from the Old Jim mine in Kentucky, at the edge of the Old Jim lamprophyre dike. The mineral occurred as a crystalline aggregate of a whitish pink color, with curved rhombohedral cleavage faces (Ulrich and Smith, 1905). Other occurrences have been reported in the district, but some mineralogists classify it as a ferroan dolomite. All material analyzed by Heyl and others was ferroan dolomite, except a little along the dikes (A. V. Heyl, 1989, personal communication).

Aragonite $CaCO_3$

Aragonite has been reported from the Dyers Hill mine (Tibbs, 1974); as coatings on calcite and as *flos ferri* in the Minerva No. 1 and other mines (T. Huizing, personal communication); and coating rhombohedral calcite crystals in the Davis-Deardorff mine (James Below, personal communication).

Asphaltite hydrocarbon

Asphaltite/grahamite are mineralloids occurring throughout the district. The host rock in the region contains significant petroleum reserves, producing thousands of barrels of oil each year (especially in areas north and east of the district). It is probable that the district was a major oil dome in the Permian period, before the northeast faults formed (A. V. Heyl, 1989, personal communication). These mineralloids can be found as inclusions, especially in fluorite, calcite and quartz and/or as coatings. They commonly occur in mineral fractures. Strong petroliferous odors are often noticeable when breaking masses of fluorite, other minerals, and host rock.

Ulrich and Smith (1905) reported pockets of oil in the Bonanza mine in Kentucky. Liquid petroleum is abundant in early yellow-stage fluorite fluid inclusions (A. V. Heyl, 1989, personal communication). The Hill mine, north of Cave in Rock, had an unusual occurrence of asphaltite/grahamite: B. L. Perry reported a 3 by 10-foot cavity, 1 to 1.5 feet high, half filled with asphaltite. The bituminous material was mostly vitreous, with a 3-cm-thick layer of a dull frothy material at the top (Grogan and Bradbury, 1968). In the Minerva No. 1 mine (G. Montgomery, 1986, personal communication), in the period from 1970 to 1975, live crude oil was a serious nuisance, appearing in cavities in the fluorite-zinc ores of the Renault Formation. It had to be collected in barrels and hoisted to the surface. Crude oil was harmful to fluorite flotation in the mill, as it caused excess frothing and loss of concentrate. Sometimes some of the oil could be floated off the surface of thickeners before flotation of fluorite or sphalerite. Unfortunately, there was not enough crude oil to be considered economically interesting.

Azurite $Cu_3(OH)_2(CO_3)_2$

Azurite has not been reported in the literature, although Richardson (1925) predicted its occurrence. The writer has found what is believed to be azurite in microscopic grains in association with malachite from the dump at the Minerva No. 1 mine. Additional azurite may have been found on the dumps adjacent to the heavy media mill and the Annie L No. 45 shaft in the Cave in Rock district. Brecke (personal communication) reports finding small amounts of azurite as films on quartz at the Patrick lead mine.

Barite $BaSO_4$

Barite is widespread throughout the district although, as mentioned earlier, it tends to become most prominent toward the periphery of the district. Sources of good barite crystals are numerous, including the Minerva No. 1, Denton, and Annabel Lee mines all producing outstanding specimens with colors ranging from white, to brown, yellow, orange and blue (Lillie, 1988). The Gaskins mine also produced some interesting straw-yellow barite (Carlon and Winchell, 1975). Historically, the Crystal and Victory mines produced beautiful barite specimens.

Barite crystals are typically from microscopic to over 3 cm in length; they occasionally reach lengths of 10 cm (e.g. at the Gaskins and West Green mine; Carlon and Winchell, 1975).

Barite is thought to be near the end of the paragenetic sequence, though this may not be completely true. This writer possesses a fluorite cast after barite. The fluorite appears to be from the "P2" zone of Richardson and Pinckney (1984), having a pale purplish blue color. The original barite crystal was nearly 10 cm in length and slightly more than a centimeter thick. Additionally, this writer frequently finds barite inclusions in yellow fluorite, as well as yellow crystals over barite in deposits along Spar Mountain in the Cave in Rock district. These may result from barite replacing earlier fluorite.

Barite has been found in stalactitic form in several localities including the Annabel Lee mine. One pocket discovered in this mine in 1988 contained barite in a stringy meshwork. Barite has also been found in casts after witherite and celestite at the Minerva No. 1 mine, the Annabel Lee mine and at the old Cleveland mine.

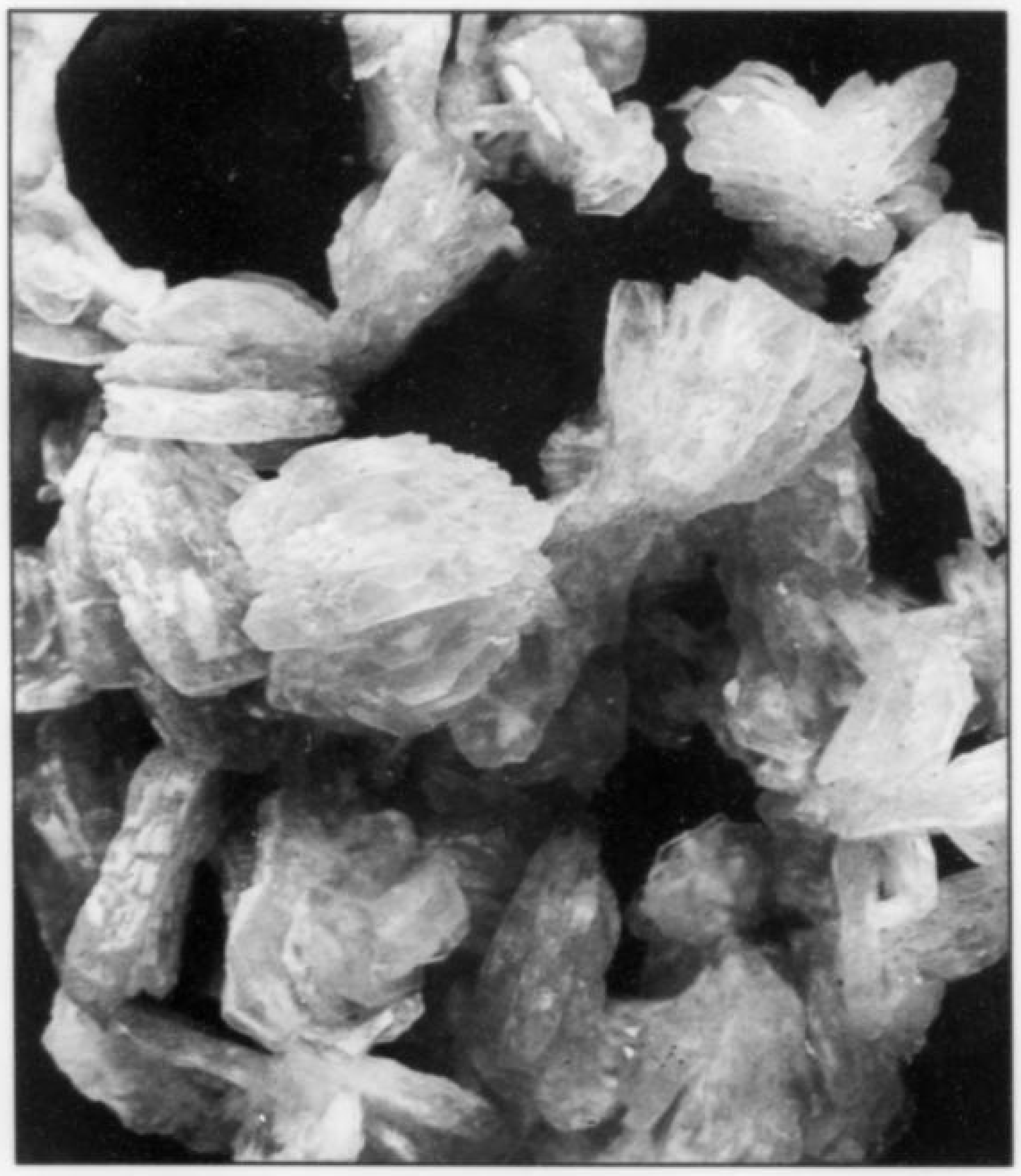


Figure 32. **Pale blue barite crystals on purple fluorite, 6.3 cm, from the Minerva #1 mine. Steven Neely collection; Jeff Scovil photo.**

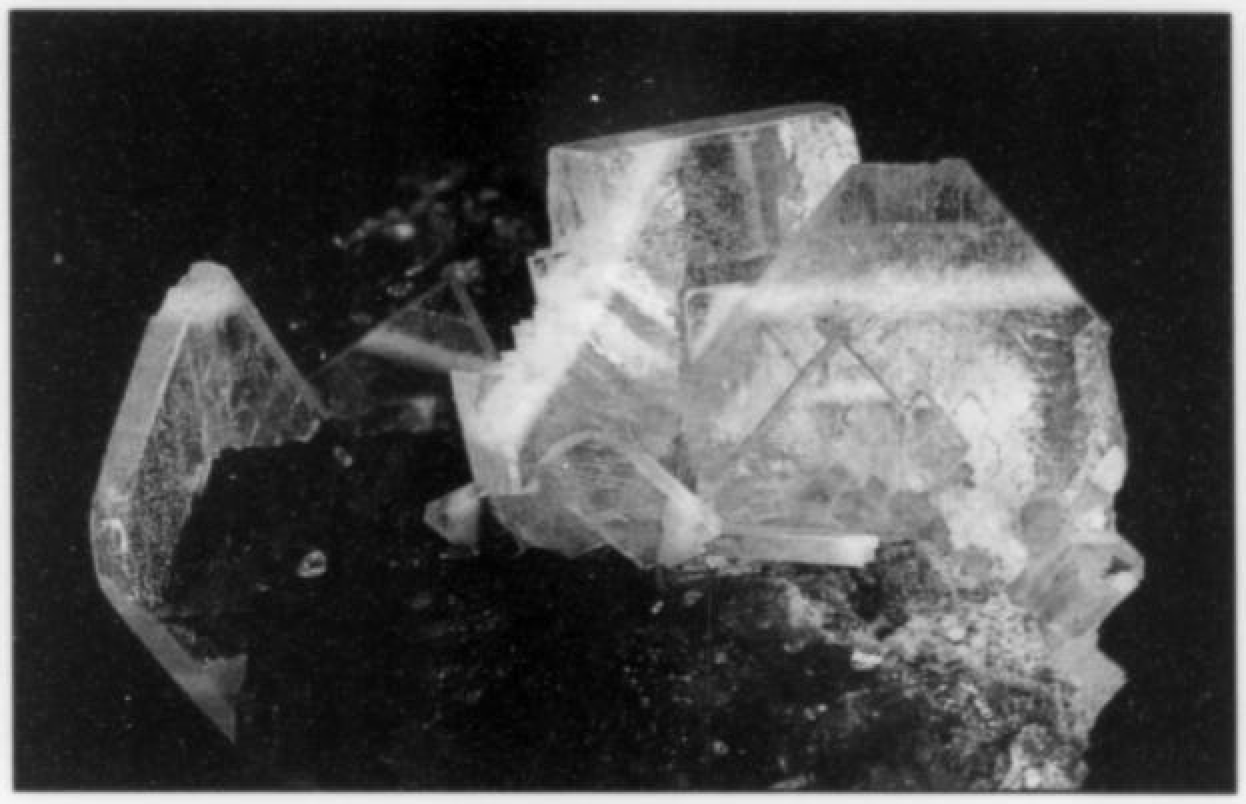


Figure 33. **Color-zoned barite crystals on purple fluorite, 4.2 cm, from the Denton mine. Bill and Carol Smith collection; Jeff Scovil photo.**

Figure 34. **Barite crystals with purple fluorite on matrix, 10.8 cm, from the Rosiclare level, Denton mine. Ross Lillie collection; Jeff Scovil photo.**

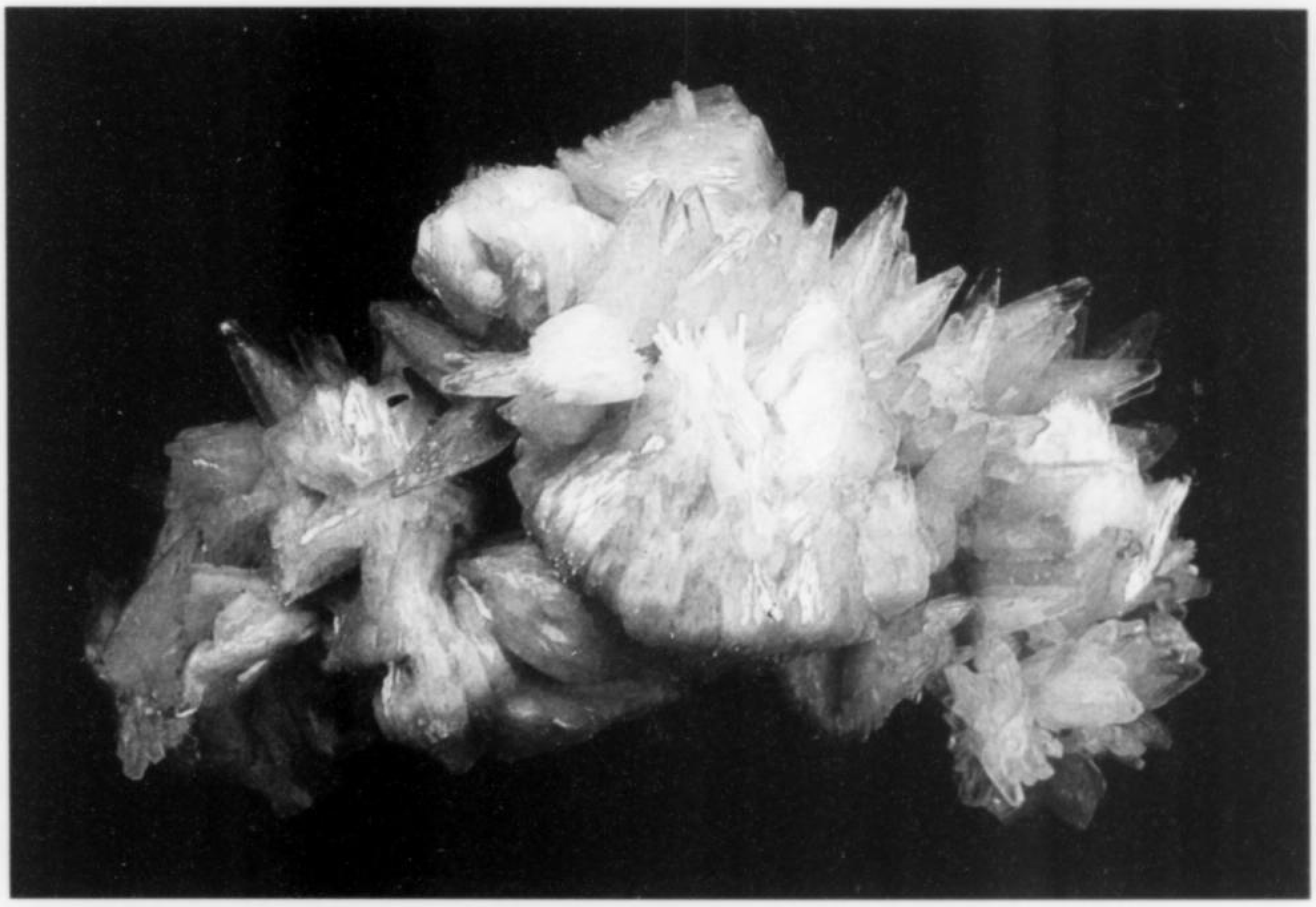


Figure 35. **Pale yellow calcite and pale blue barite crystal group, 11.1 cm, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #124612; Jeff Scovil photo.**

In addition to the mines mentioned above, there are other mines which contained large barite deposits. The Ainsworth and Mico mines, southeast of Cave in Rock (in Kentucky), produced substantial tonnages of barite, though no unusual specimens. The Pygmy mine area near Mexico, Kentucky, also produced large quantities of barite. Numerous "gravel spar" deposits of barite were reported in the Kentucky portion of the district (Anderson *et al.*, 1982).

Benstonite $(Ba,Sr)_6(Ca,Mn)_6Mg(CO_3)_{13}$

Benstonite is a rare double carbonate that has been found at the Minerva No. 1 mine. White and Jarosewich (1971) reported it as occurring "as flat, unmodified rhombohedral crystals which appear to be arranged epitaxially around spinelike crystals of calcite." The color ranges from pale yellow to pale yellowish brown. Specimens not intimately associated with calcite tend to form crusts of saddle-shaped rhombs less than 1.2 cm across. Barite sometimes forms a white coating over benstonite. Benstonite and witherite tend to occur within 500 feet of the main shaft at the Minerva No. 1 mine (G. Montgomery, 1987, personal communication).

Calcite $CaCO_3$

Calcite is the most common mineral in the fluorite district, occurring in virtually every known deposit. It is especially abundant in the veins, occurring as white to pale gray (rarely pink),

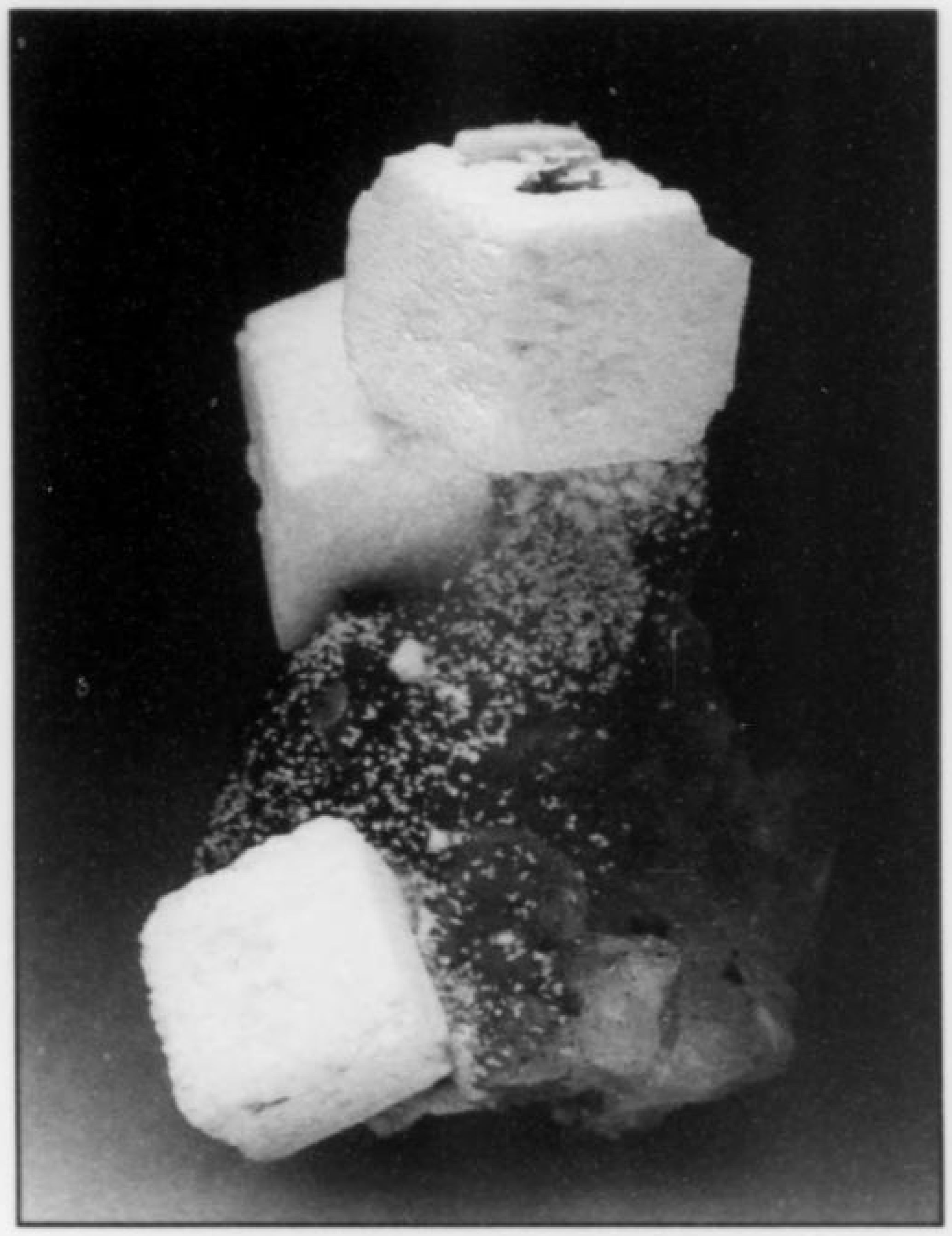


Figure 36. Barite pseudomorphs after celestine on purple fluorite, 6.8 cm, from the Sub-Rosiclare level, Annabel Lee mine. Ross Lillie collection, Jeff Scovil photo.

Figure 37. Barite pseudomorphs to 3.1 cm after witherite, from the Minerva #1 mine. Harvard collection #123311; Jeff Scovil photo.

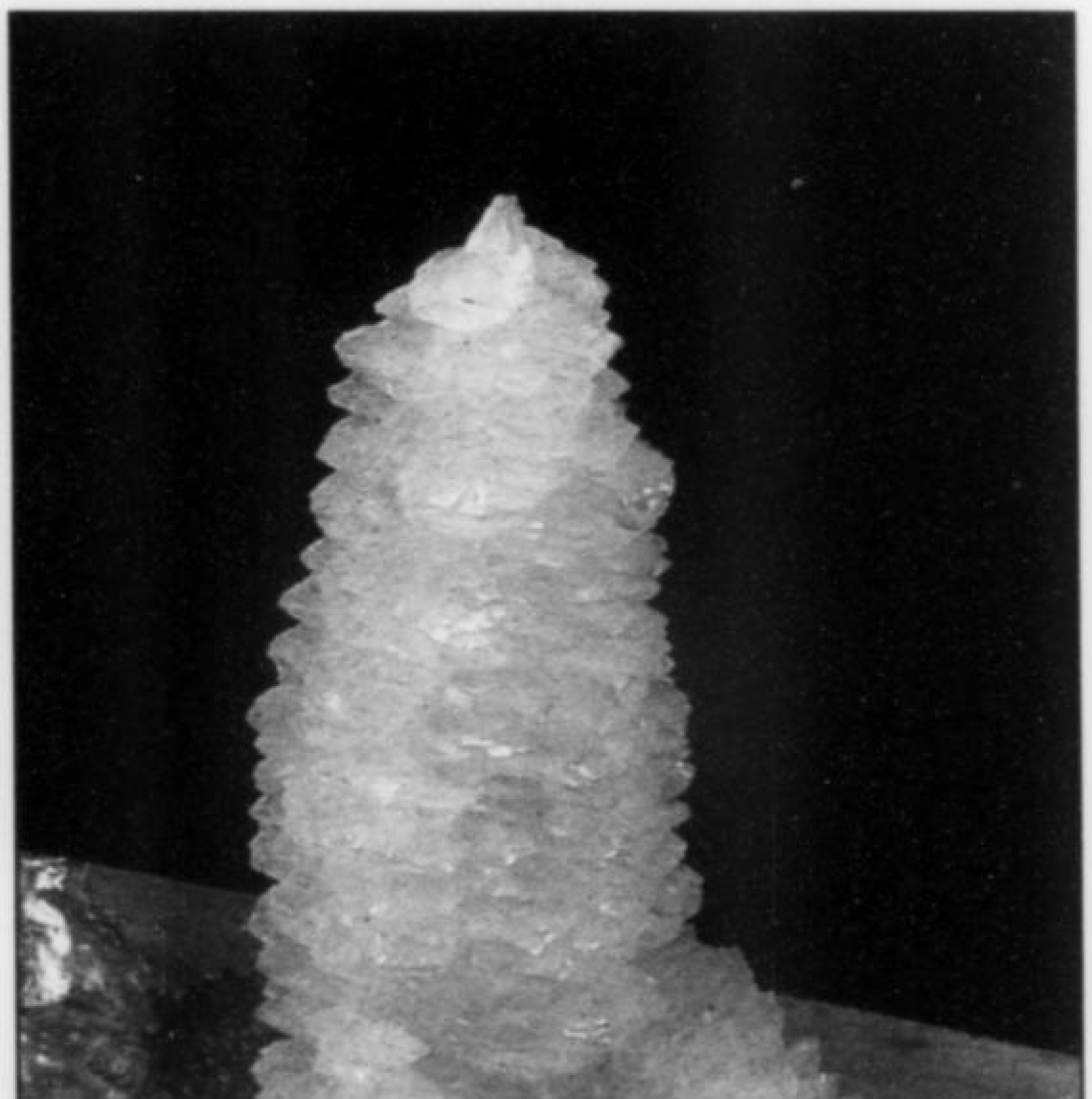


Figure 38. Golden yellow calcite twin on matrix, 6.5 cm, from the Sub-Rosiclare level, Denton mine. Ross Lillie collection; Jeff Scovil photo.

Figure 39. Benstonite crystal aggregates on yellow fluorite, 7.1 cm, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #124592; Jeff Scovil photo.

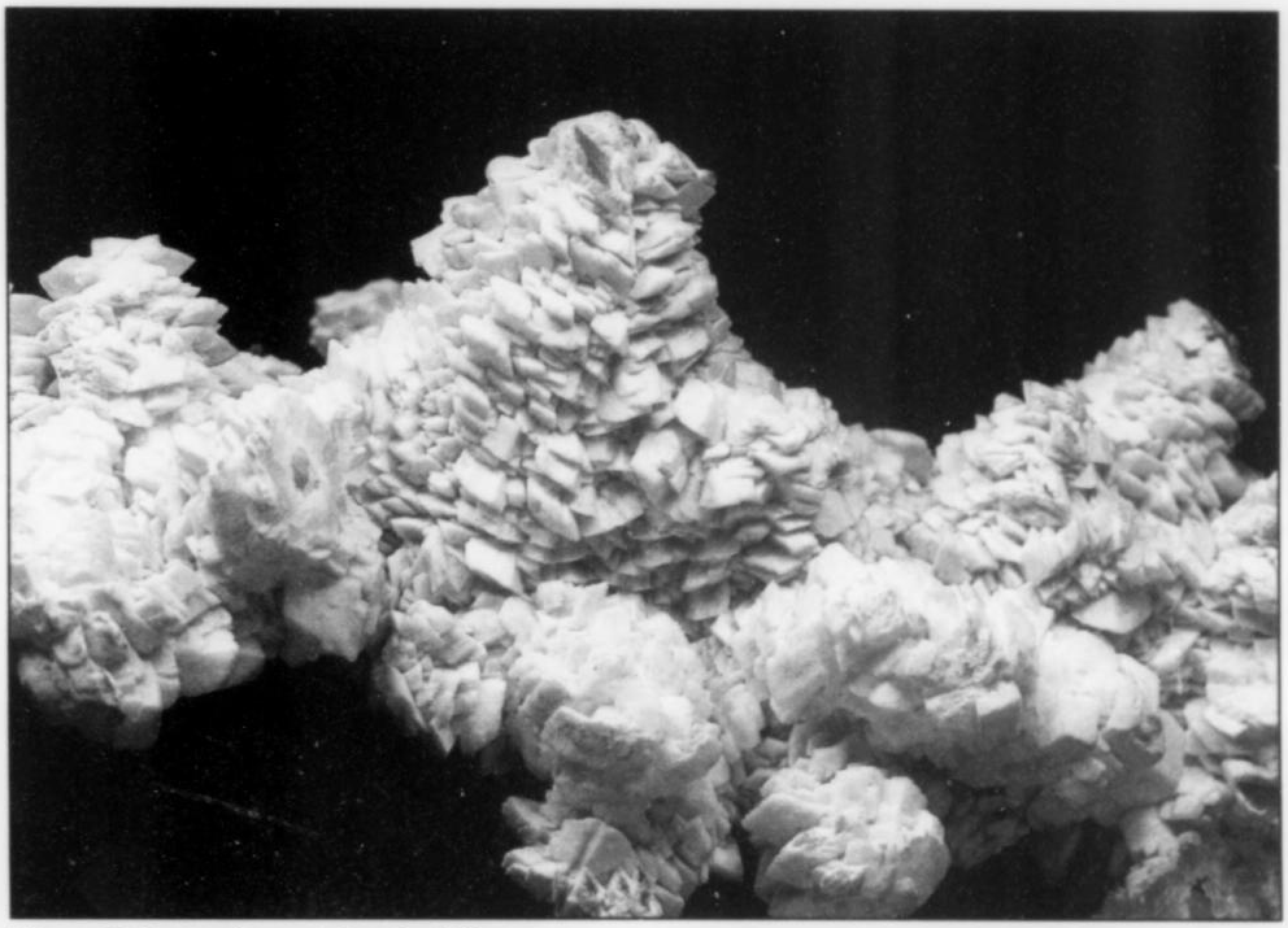


Figure 40. **Benstonite crystals epitaxially coating scalenohedral calcite, 7 cm, from the Minerva #1 mine. Steven Neely collection; Jeff Scovil photo.**

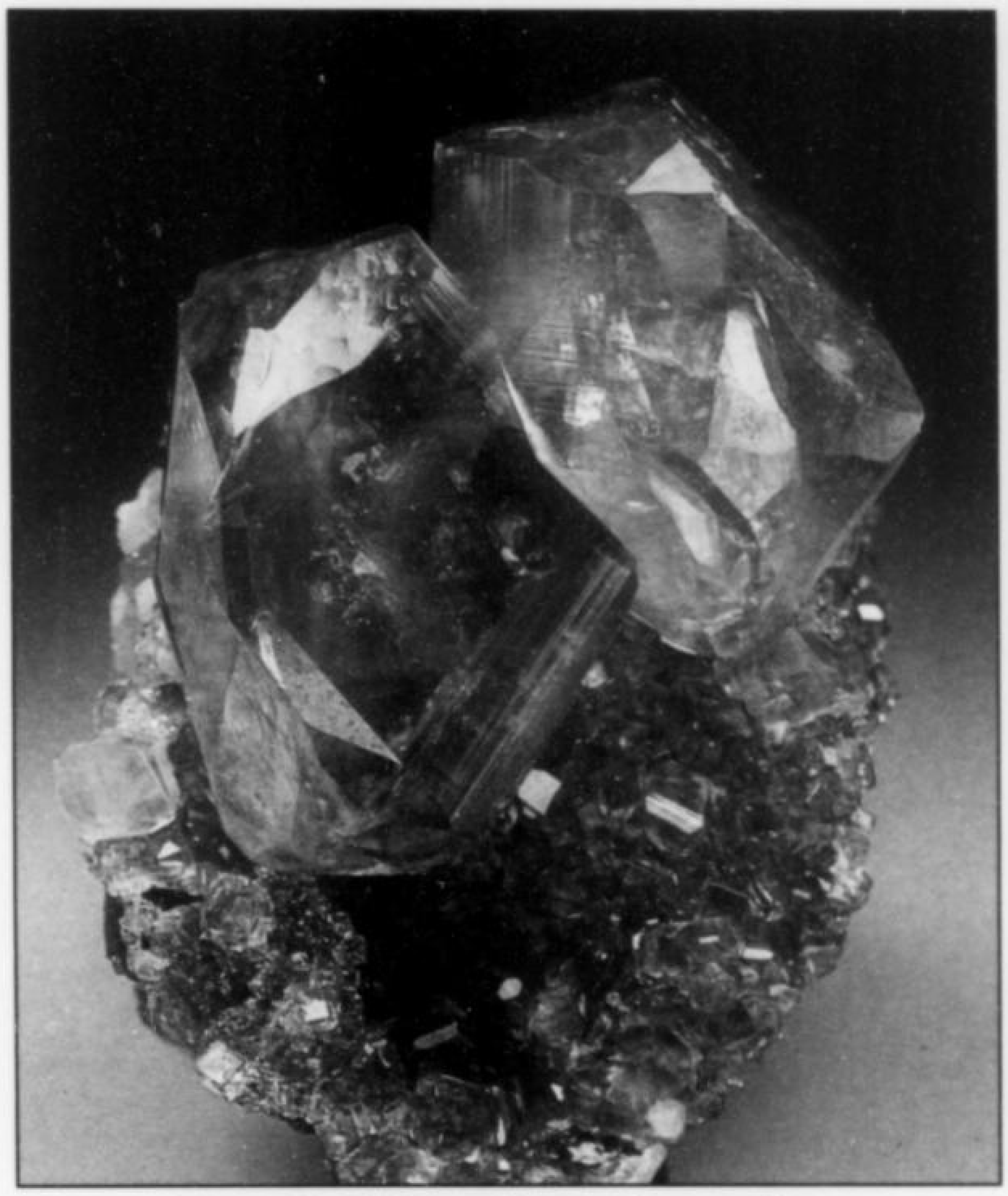


Figure 41. **Golden yellow calcite crystals on purple fluorite, 6.2 cm, from the Denton mine. Ross Lillie collection; Jeff Scovil photo.**

Figure 42. **Scalenohedral calcite twin (0001) (8 cm) on celestine crystals, from the St. Louis level, Annabel Lee mine. Ross Lillie collection; Jeff Scovil photo.**

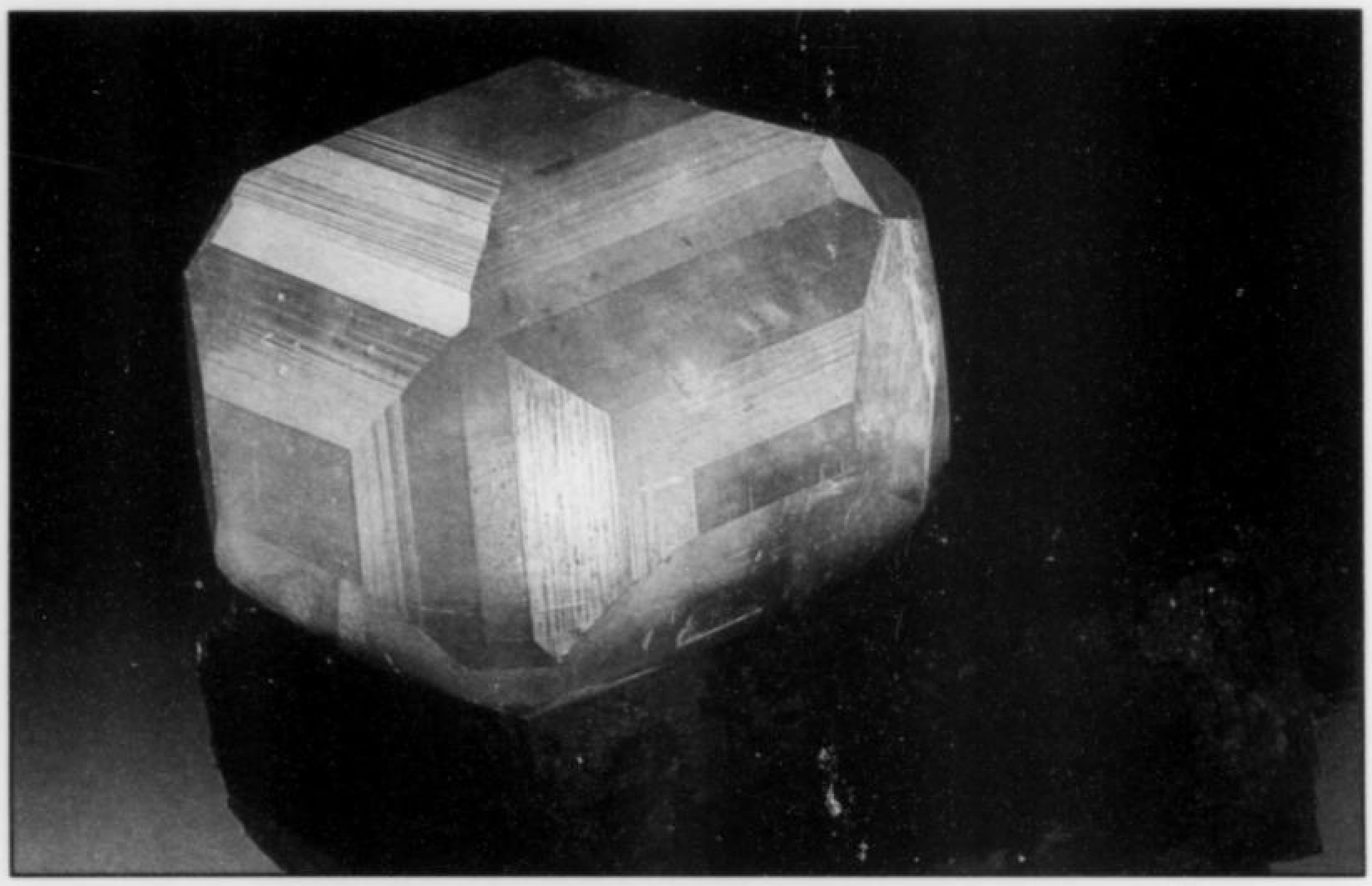


Figure 43. Yellowish calcite crystal, 4.5 cm, on dark purple fluorite, from the Rosiclare level of the Denton mine. Ross Lillie collection; Jeff Scovil photo.

Figure 44. Golden yellow calcite crystal, 3.2 cm, on purple fluorite, from the Denton mine. Ross Lillie collection; Jeff Scovil photo.

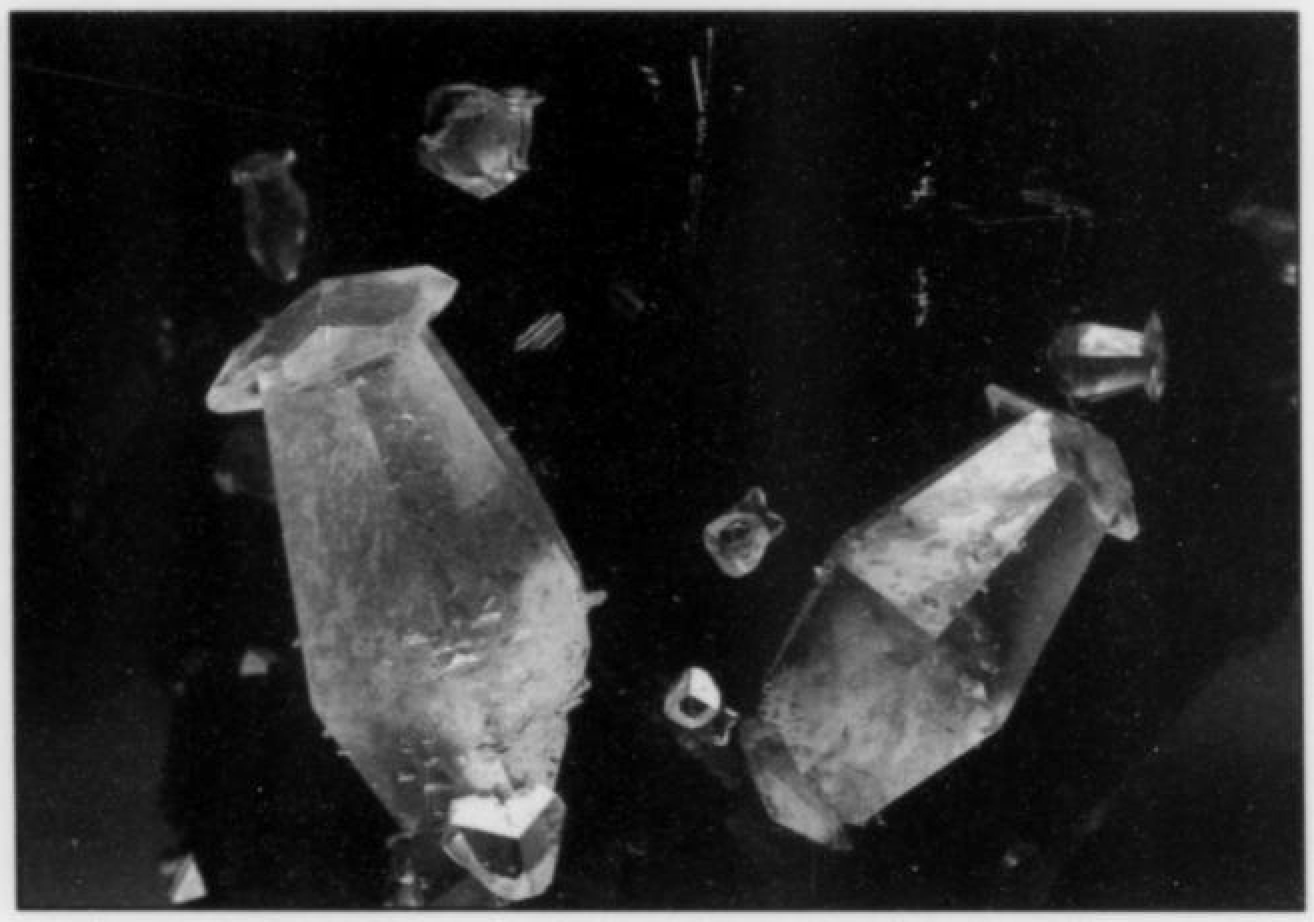


Figure 45. "Nailhead" calcite crystals to 3.2 cm on purple and yellow zoned fluorite, from the Denton mine. William Severance collection; Jeff Scovil photo.

Figure 46. Calcite crystals on fluorite, 5.1 cm, from the Denton mine. William Severance collection; Jeff Scovil photo.

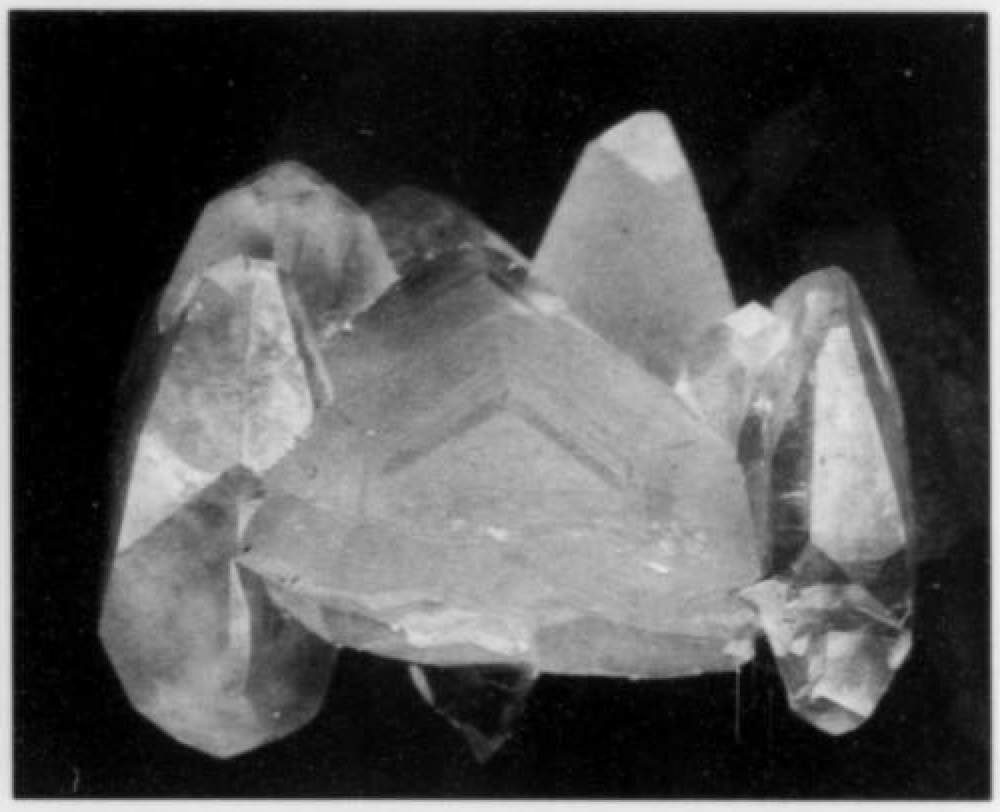


Figure 47. Low-angle calcite crystal with satellite scalenohedral crystals epitaxially attached, 3.7 cm, from the Sub-Rosiclare level of the Denton mine. Ross Lillie collection; Jeff Scovil photo.

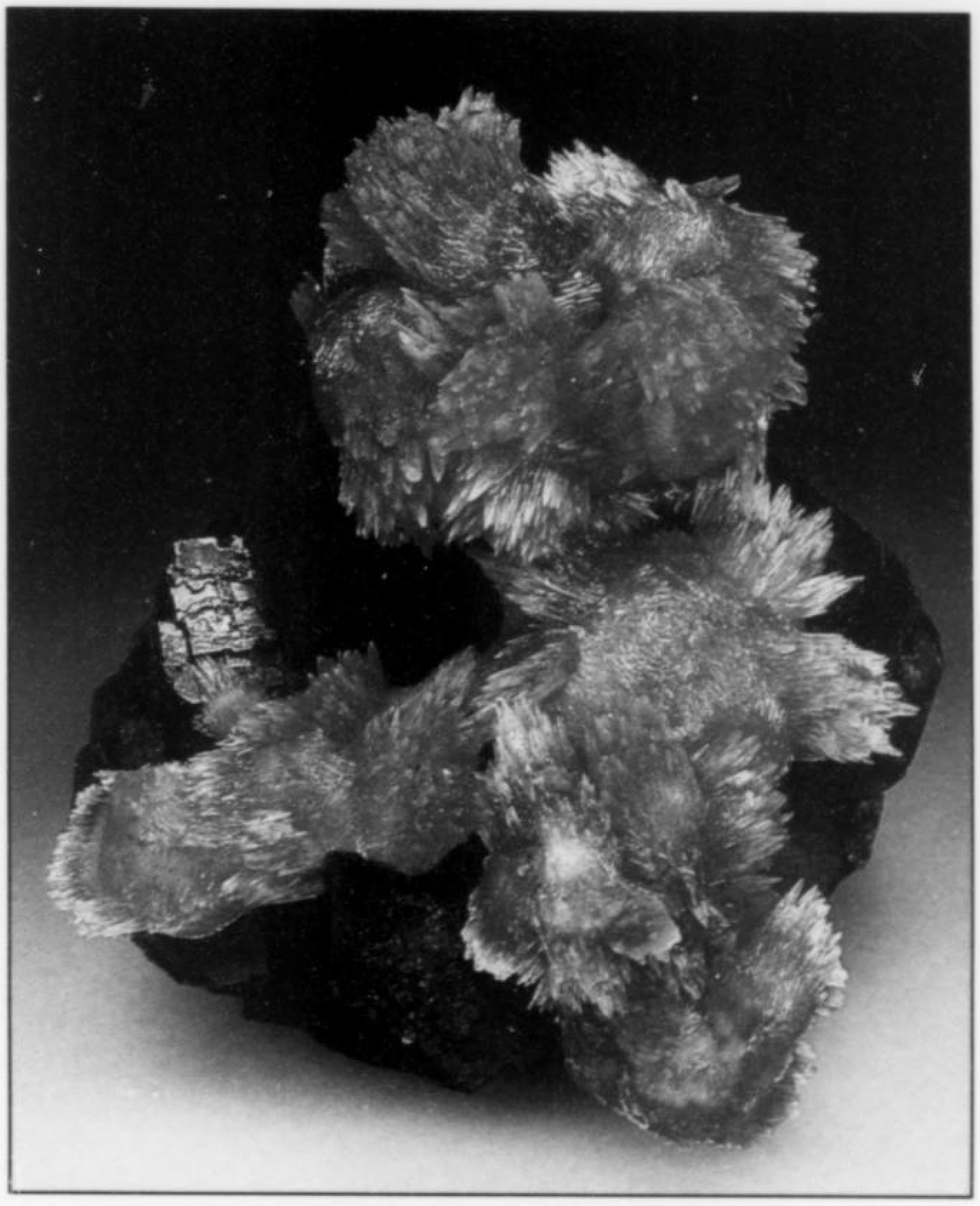


Figure 48. Golden yellow calcite crystal sprays on dark purple fluorite, 9.5 cm, from the Minerva #1 mine. Ross Lillie collection; Jeff Scovil photo.

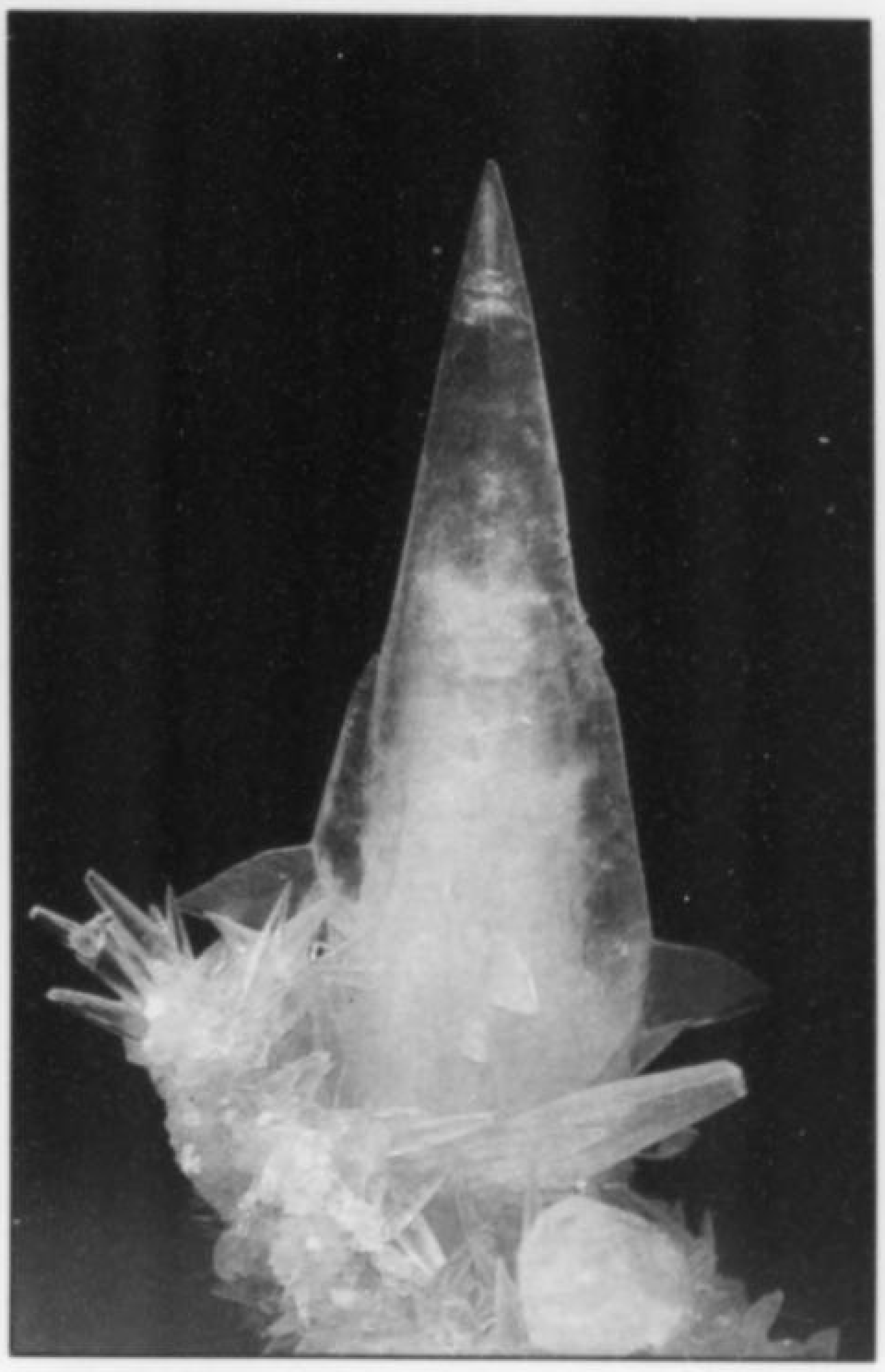


Figure 49. Calcite crystal group, 6.5 cm, from the Bethel level, Annabel Lee mine. Ross Lillie collection; Jeff Scovil photo.

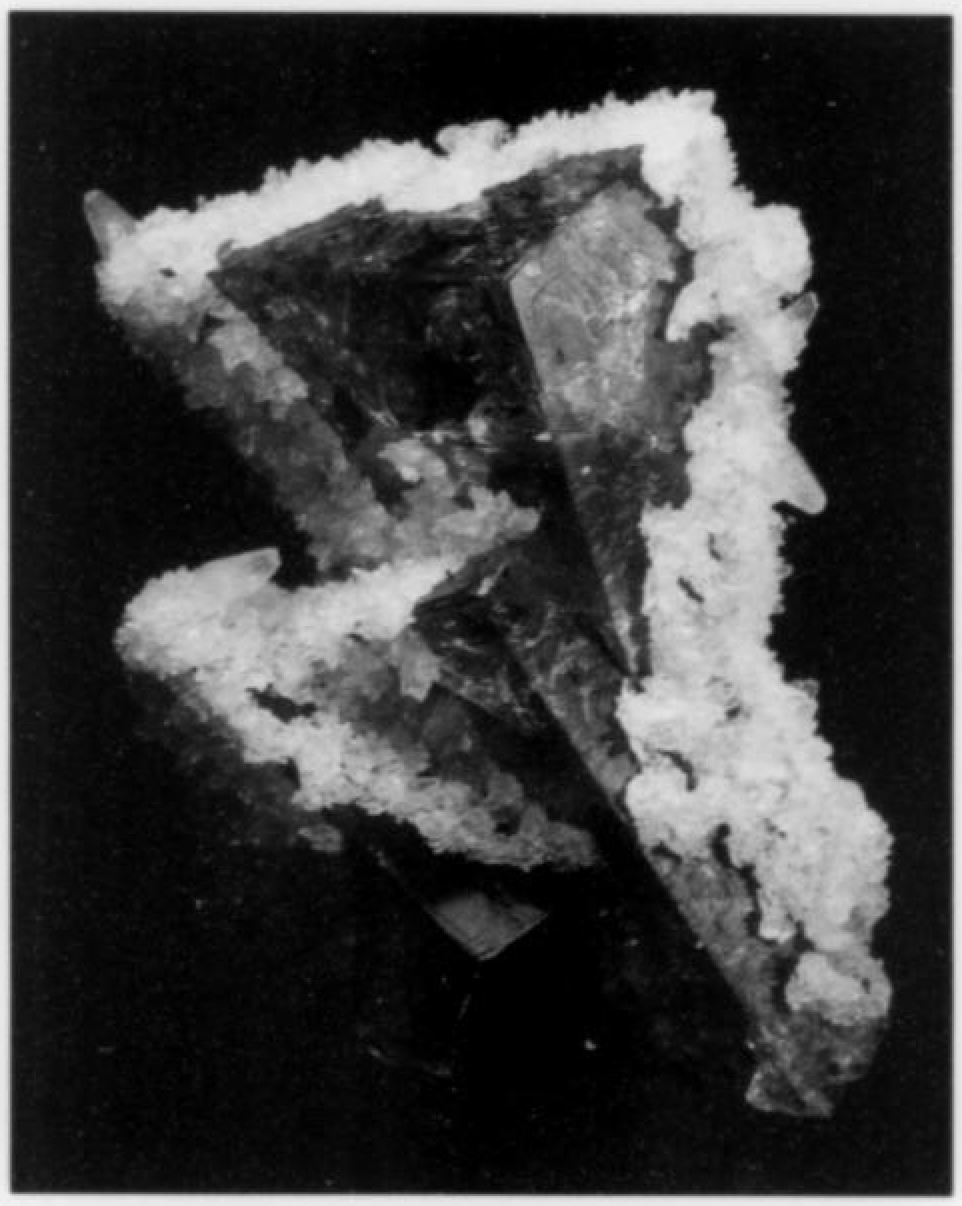


Figure 50. White calcite on golden yellow fluorite, 10.5 cm, from the Mahoning #1 mine. Bannister collection, Harvard Mineralogical Museum #117437; Jeff Scovil photo.

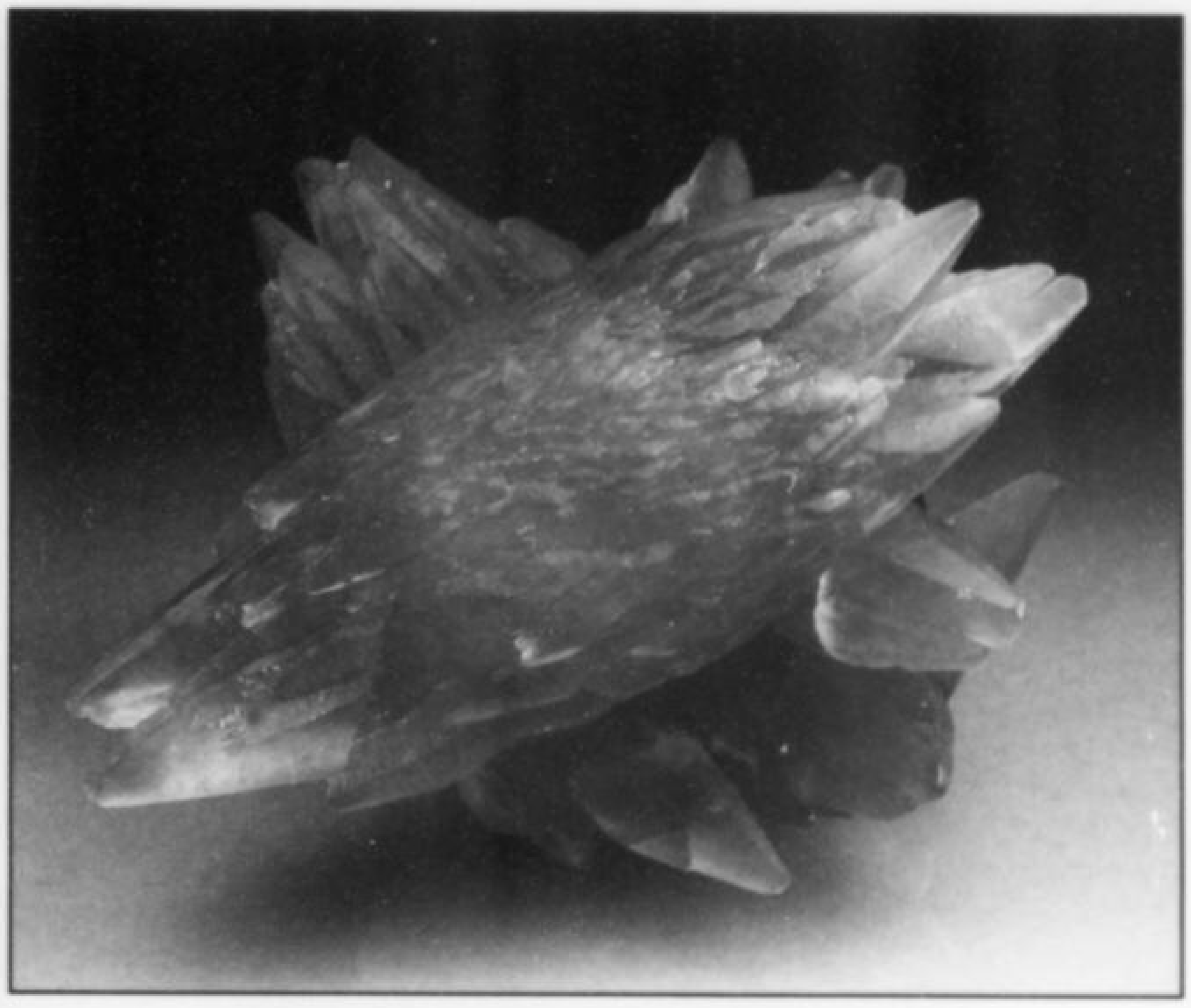


Figure 51. Golden yellow calcite crystal group, 7.5 cm, from the Minerva #1 mine. Ross Lillie collection; Jeff Scovil photo.

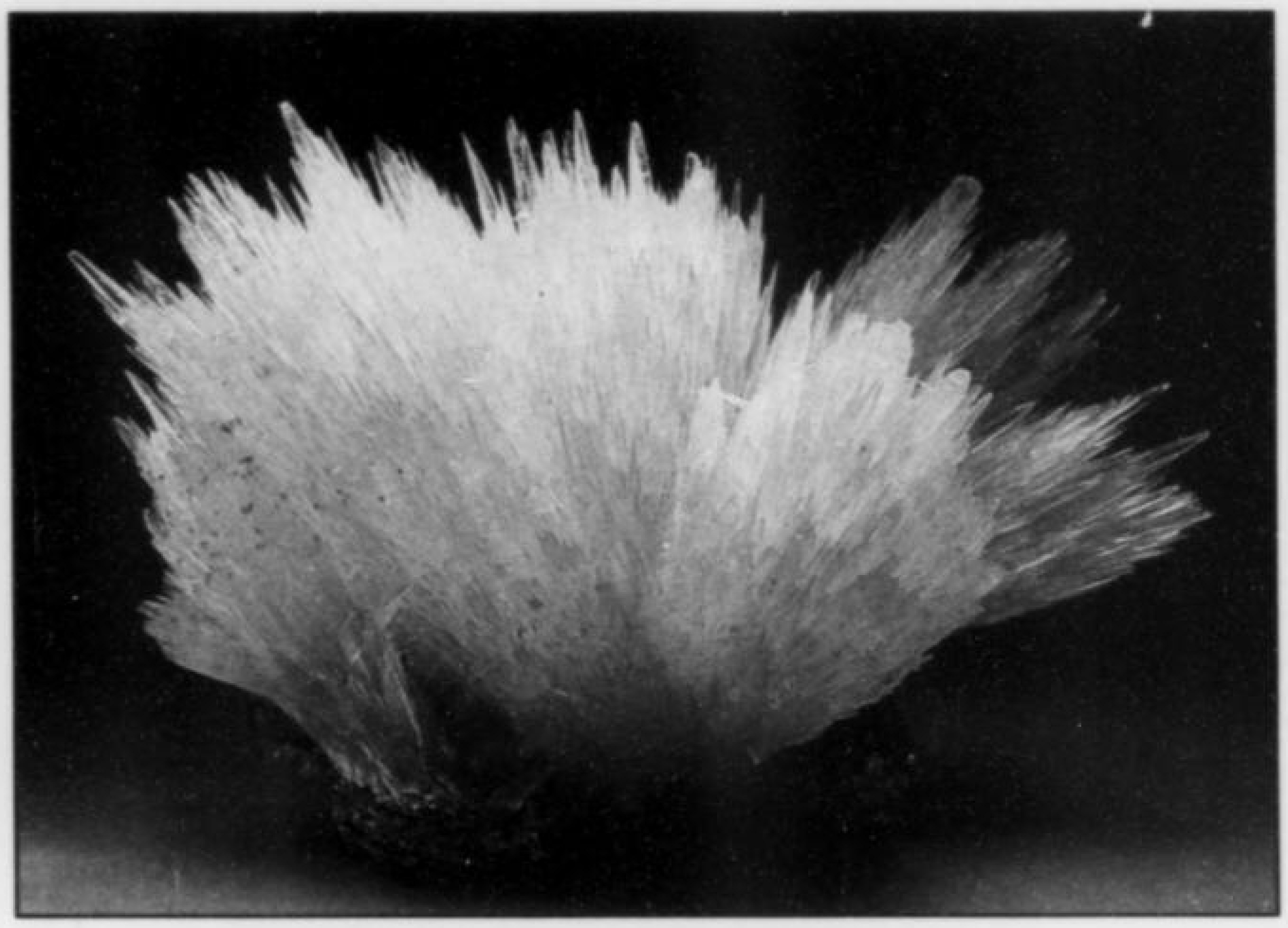


Figure 52. **Golden yellow acicular calcite crystal group, 13 cm, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #129840; Jeff Scovil photo.**

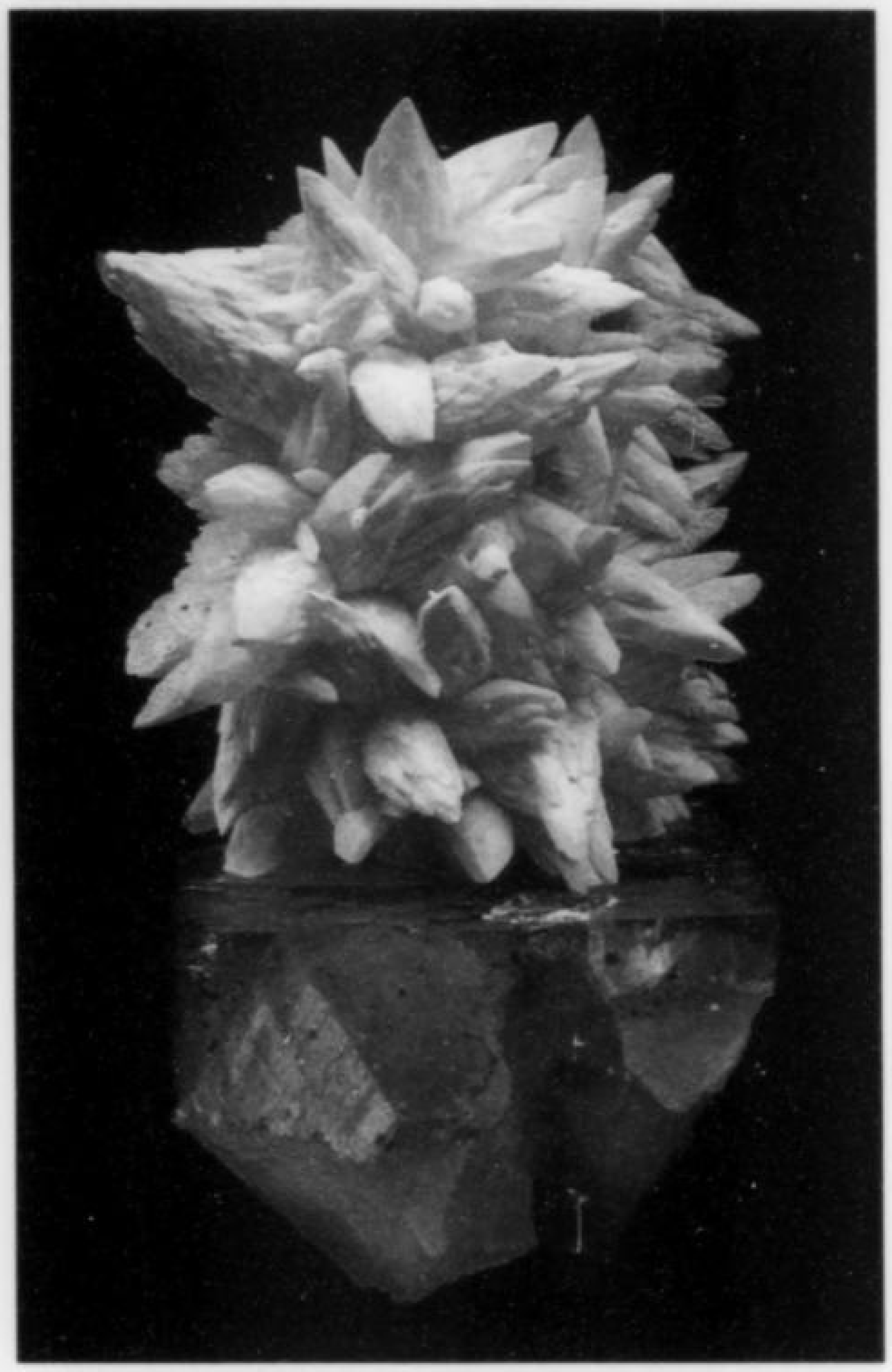


Figure 53. **White calcite crystal group on yellow fluorite, 10.5 cm, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #124601; Jeff Scovil photo.**

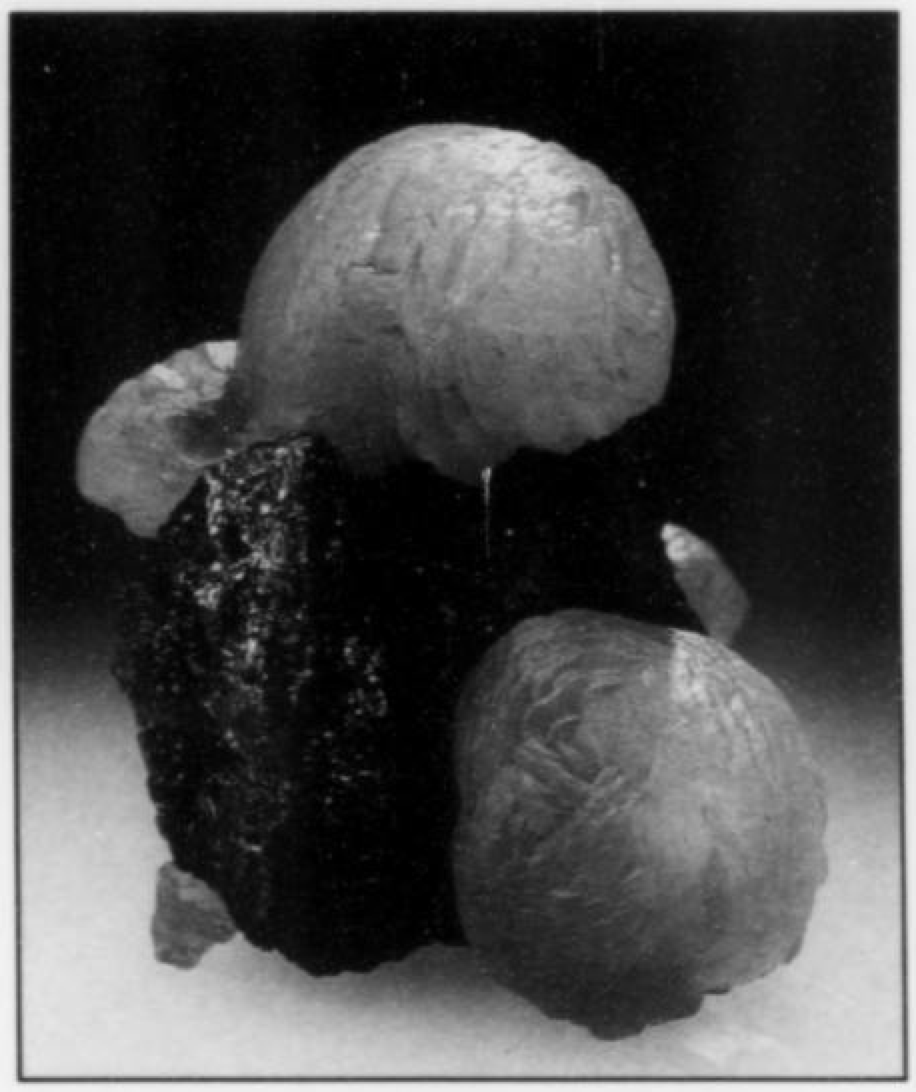


Figure 54. **Spheroidal calcite crystal aggregates with pyrite microcrystals on sphalerite, 5.3 cm, from the Rosiclare level, Minerva #1 mine. Ross Lillie collection; Jeff Scovil photo.**

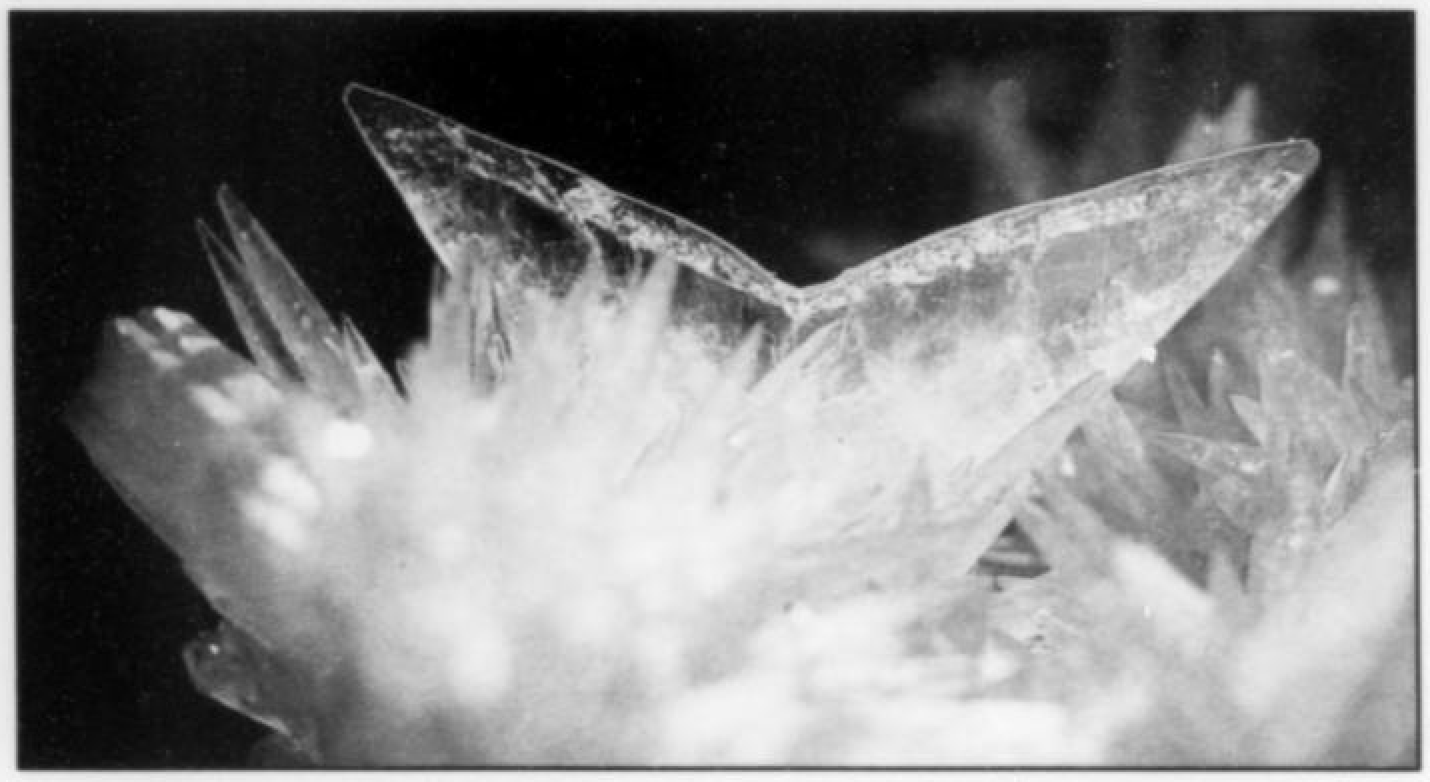


Figure 55. **Calcite "butterfly" twin, 3.1 cm, from the Bethel level, Annabel Lee mine. Ross Lillie collection; Jeff Scovil photo.**

opaque masses. The early rhombohedral calcite rarely forms terminated crystals and is usually intergrown and highly fractured. In these deposits, scalenohedral crystals measuring 8 to 10 cm have been found, though 2 to 5 cm is more common. Tibbs (1974) reported crystals up to 45 cm (18 inches) from the Dyers Hill mine.

In the bedding replacement deposits, early rhombohedral calcite is rare. Most calcite crystals are in the late-forming scalenohedral class. According to Lillie (1988) the Denton mine has produced the finest calcites of any orebody in the district. Many calcite associations are distinctive from specific orebodies. Annabel Lee mine calcite from the southern orebody is distinctively honey-brown in color, frequently doubly terminated, and twinned on (0001). Calcite from the Annabel Lee north orebody is pale yellow to white and of a very acute scalenohedral habit, similar (but not identical) to that found in the Minerva No. 1 mine.

One interesting specimen found by this writer is a microscopic, doubly terminated calcite in the form of a first-order prism capped by a negative rhombohedron perched *on* a sphere of bitumen. Calcite may be coated with barite, bitumen or (at one location on Spar Mountain) gypsum. Calcite frequently precipitates on one side of a crystal face (due to gravity or solution flow) forming a snowy appearance.

Richardson and Pinckney (1984) detailed the paragenesis of three calcite forms from the Deardorff mine.

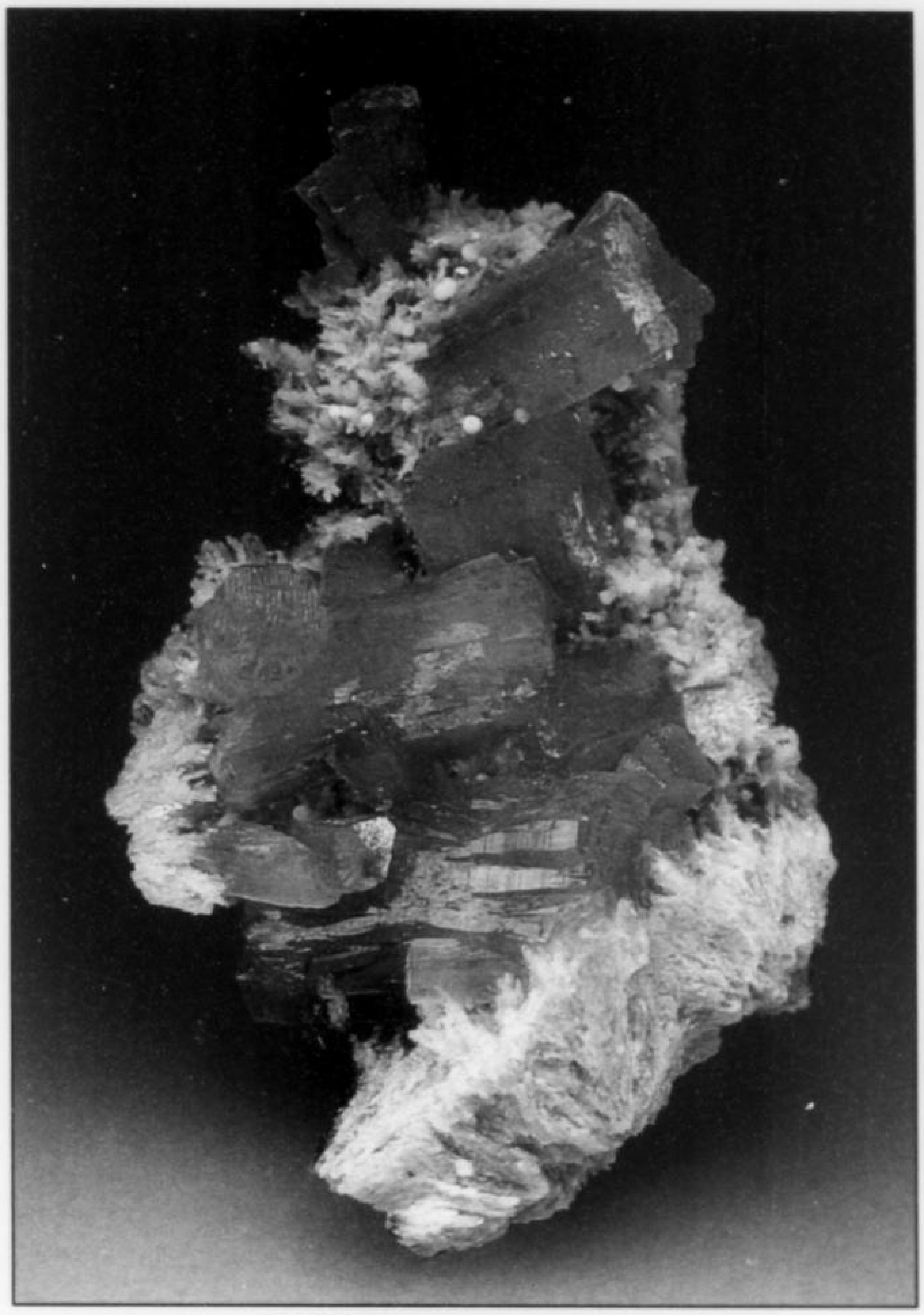


Figure 56. **Celestine crystal group, 7.5 cm, from the St. Louis level, Annabel Lee mine. Ross Lillie collection; Jeff Scovil photo.**

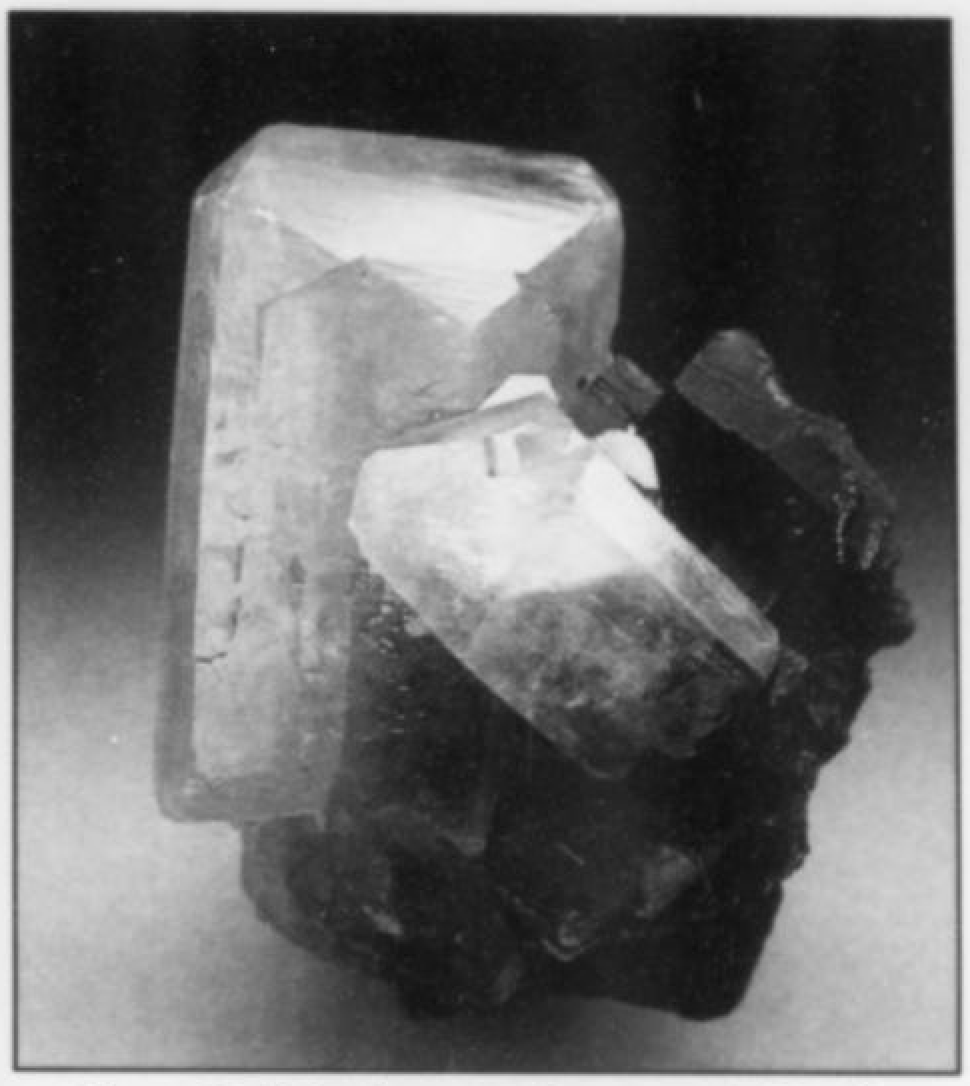


Figure 57. **Celestine crystals on purple fluorite, 5 cm, from the St. Louis level, Annabel Lee mine. Ross Lillie collection; Jeff Scovil photo.**

Figure 58. **Celestine crystal group, 4.6 cm, from the St. Louis level, Annabel Lee mine. Ross Lillie collection; Jeff Scovil photo.**

Celestine $SrSO_4$

Celestine is very uncommon in the district, having only been reported four times. The Jameson prospect, 8 miles north of Salem, Kentucky, was the first published occurrence. Hardin and Thurston (1945) reported celestine from a vein at this location. Miners found pale sky-blue, distorted, tabular crystals about 2 cm wide and 5 mm thick, They were in crystal aggregates at a depth of 30 feet. In 1972, pale blue tabular crystals up to 3 cm were reported in the Barnett mine. Crystals with chisel-shaped terminations were intergrown in flat plates 7 to 10 cm across (Lillie, 1988).

G. Montgomery (1986, personal communication) reported celestine in the Minerva No. 1 mine, occurring with strontianite and witherite from the west orebody.

The Annabel Lee mine has been the most productive source of celestine in the district. Crystals have been found in a variety of forms including doubly terminated barrel shapes, disks and crusts, with individual celestine crystals as large as 3 cm. Associated minerals include fluorite, barite, calcite and (to a lesser extent) sphalerite. Barite casts after rhombic prisms have also been found.

Cerussite $PbCO_3$

Cerussite is sometimes found with galena in drusy coatings, as tiny gray or chalky white acicular or colorless tabular crystals, and as dull, earthy, compact masses. Cerussite is much more abundant than anglesite, but is still quite scarce in the district. This mineral occurs where galena has been deeply weathered, as at the Patrick lead mine and Conn's mine in Illinois and the Hickory Cane mine in Kentucky. E. A. Brecke (1989, personal communication) observed this mineral on Lead Hill and at the Patrick lead mine, where galena has altered to secondary lead minerals. Some pure white, glassy crystals were found attached to chert. Attempts to obtain matrix specimens were frustrated, as the crystals broke off with blows of the pick.

Chalcopyrite $CuFeS_2$

Chalcopyrite is one of the more common sulfides, though never found in economic quantities in the district. Crystals form simple

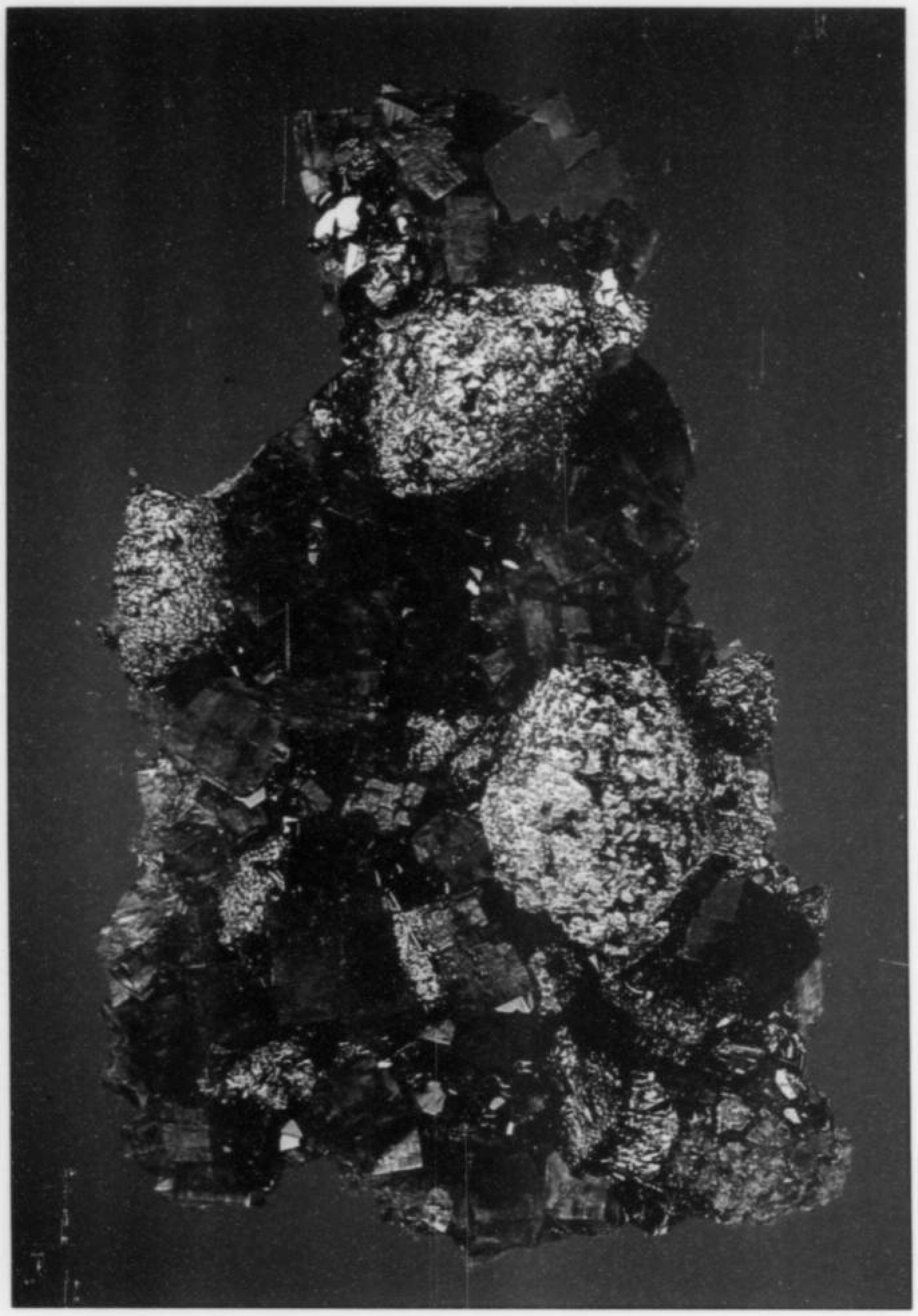


***Figure 59.* Chalcopyrite epitaxial on black sphalerite with purple fluorite, 12.6 cm, from the Denton mine. Marvin Rausch collection; Jeff Scovil photo.**

tetrahedrons on or in fluorite, and also occur as nail-shaped inclusions. Most crystals are 1 to 3 mm in length. Bastin (1931) reported a 4-pound mass occurring in white fluorite at the 250-foot level of the Hillside mine. This was an exceptionally large mass. The dumps around the Rosiclare Lead and Spar Company mill contain larger masses of chalcopyrite (as evidenced by their alteration to malachite), in fluorite and other matrix, than will be found on mine dumps in the Cave in Rock area. Selective coating of chalcopyrite on fluorite was noted at the Hillside mine. It occurs at other mines as well. Nail-shaped crystals of chalcopyrite in fluorite are common in the bedding replacement deposits. Crystals are usually oriented at right angles to the fluorite cube face, with points toward the center (Weller *et al.*, 1952). It is frequently present as inclusions along color zone boundaries (see discussion under "Paragenesis").

Copper Cu

Copper was reported by Bain (1905) as small flakes in "Rosiclare ores" resulting from the reduction of chalcopyrite.

Cuprite Cu_2O

Cuprite occurs as a weathering product of chalcopyrite in vein deposits. It is not conspicuous, although it frequently accompanies malachite.

Dolomite $CaMg(CO_3)_2$

Dolomite has been reported fairly recently, as buff-colored, porous, sugary material, not in free crystals but as closely packed rhombohedrons and rarely as a stratified sandy material. It forms replacement alteration halos around the Minerva No. 1 and Deardorff mines and is generally ferroan (Hall and Heyl, 1968). Pearly white, rhombic crystals have been found on "low-grade" fluorite in the margins of the orebodies at Cave in Rock. Veinlets of dolomite and intergrown dolomite-fluorite-calcite have been found, apparently having formed very early in the period of mineralization (Brecke, 1962). This may be the same as the ferroan dolomite, ankerite and siderite reported by other writers, all early in the paragenetic sequence.

This writer has found minor amounts of dolomite in 1-mm pale brown crystals with sphalerite from the Annabel Lee mine.

Epsomite $MgSO_4 \cdot 7H_2O$

Epsomite was found by the writer as densely packed acicular crystals up to 5 mm in length coating shales in the Victory mines. It was identified by its bitter taste. Specimens removed from the mine environment quickly sublimated. This post-mining mineral has not previously been reported from the district.

Fluorite CaF_2

Fluorite was the primary economic ore, and the mineral of most significance to the collector. Untold thousands, perhaps millions of specimens have been removed by miners and collectors and have found their way into public and private collections around the world. Fluorite crystals are of the cubic habit, though sometimes rather distorted; elongated or flattened cubes are fairly common. Minor modifications include the tetrahexahedron on the (100) face or beveled crystal edges. Very rarely, a crystal will show etching on the (111) corner, forming an octahedral face. This modification can be easily differentiated from a cleavage face by its etched, frequently "stair-step" pattern. Bain (1905) first noted this form on fluorite.

Miners and hobbyists take advantage of the perfect octahedral cleavage on (111) to create "fluorite diamonds" or cleavage octahedrons. Bain (1905) noted cleavage octahedrons adorning local cabinets even back then. The technique was learned by this writer from a miner who recommended using a small chisel. (Nearly every candy dish in my house is filled with octahedrons of various sizes.) Chipping fluorite is dangerous (as you will quickly find out)! Cleavage chips with a "Mercedes"-pattern three-pointed star are fairly common, especially with purple fluorite.

Dissolution of fluorite gives a dull luster to the crystal face. In the extreme, dissolution may completely obliterate the original crystal form, leaving a spongy mass in its place. Fluorite showing dissolution is found throughout the district, though it is seldom sought by collectors and as a result is not seen on the market, unless with another marketable mineral (e.g. witherite).

Fluorite in the district comes in a wide variety of colors and an even greater number of hues and tints. The earliest yellow crystals are not especially common. As previously discussed, they are often etched and overgrown epitaxially with later generation(s) of fluorite. Yellow fluorite with mirror-like crystal faces is consequently very rare. Occasionally, yellow fluorite crystals can be found with

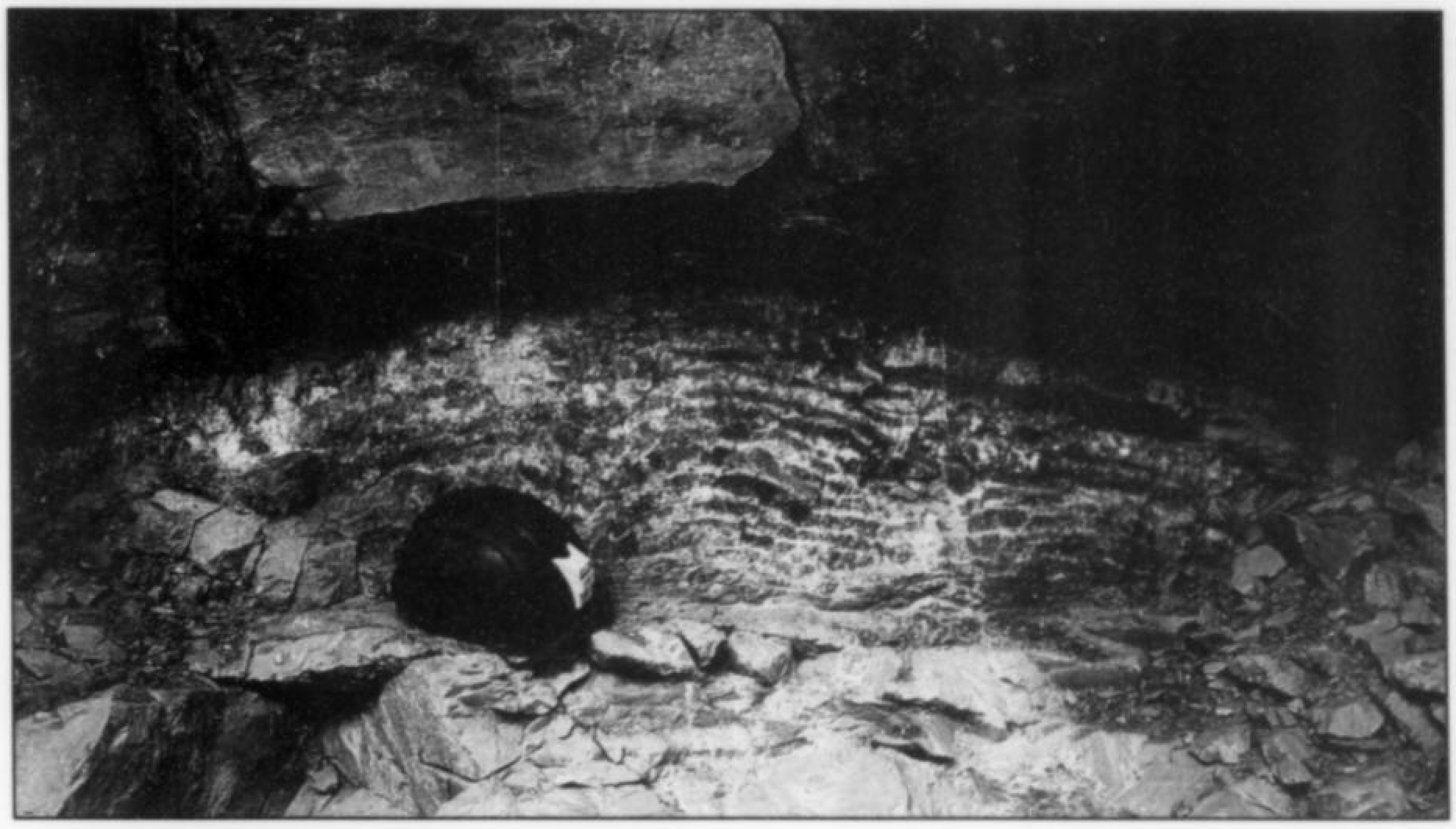


Figure 60. **Bedded "coon-tail" fluorite replacement deposits, Austin lead mine. Author's photo.**

a very thin overgrowth of purple fluorite. Yellow shades vary from pale to dark amber. Chalcopyrite coating yellow fluorite crystals represents the "Y2" generation of Richardson and Pinckney (1984).

Colorless or white fluorite occasionally occurs as crystals. Francis (1982) speculated that one reason it is not seen is because it is not as marketable as colored specimens, and as a result dealers do not stock it. During field collecting, this writer has very rarely seen white or colorless fluorite crystals. Lillie (1988) reports optically clear fluorite from the Crystal mine. White fluorite is more common in vein deposits.

Blue fluorite occurs widely throughout the district. Color tinting varies from very pale blue to bright blue to gray blue. Blues have been described as robin's-egg-blue (Francis, 1982) to aqua and sky-blue (from the Denton mine) by Lillie (1988).

Purple fluorite varies from very pale lavender to almost black. Multiple zoning of purple crystals is prized by collectors. Crystal sizes from 1 to 15 cm on an edge are common, though larger (30 cm) crystals are found in the most intense areas of mineralization. Those have often been shattered by explosive charges during mining.

A bit of luck and diligence has netted this writer rarer colors, including green and pink fluorite. The former was found as massive or botryoidal masses on the dumps of the Rosiclare Lead and Spar Company mill; the latter was found as a pair of 1-cm cubes on corroded galena at Conn's mine. Heyl (1983) reports that the green fluorite in the district contains some yttrium. It appears to be restricted to the breccia pipes and to the Rose mine at the foot of Hicks Dome. The green fluorite recovered by the writer was probably mined elsewhere and milled in Rosiclare.

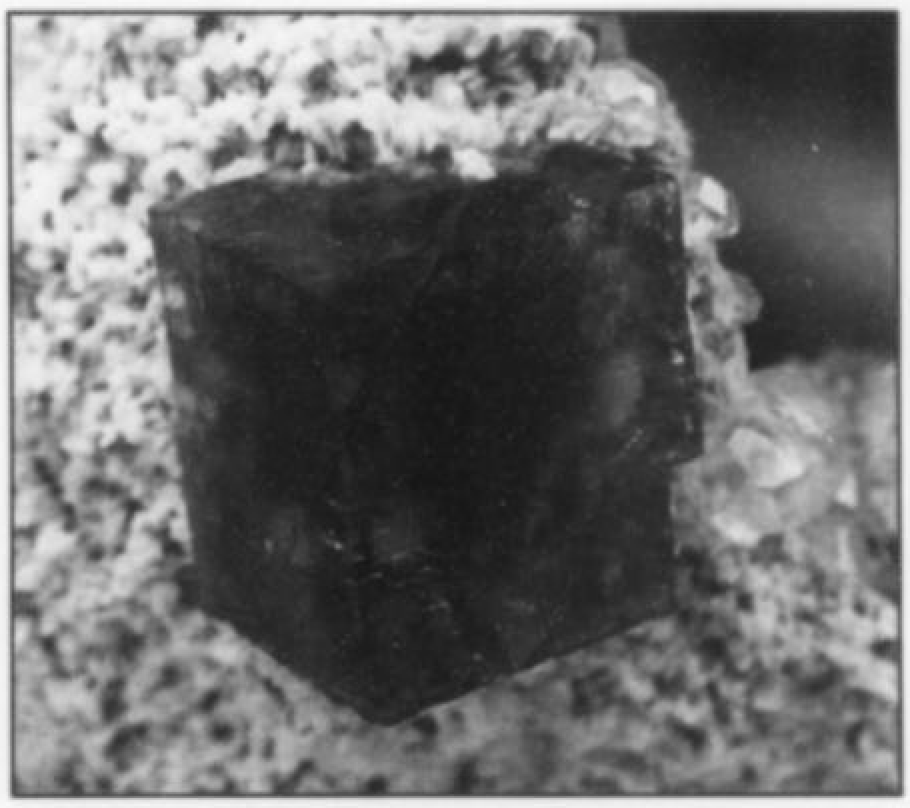


Figure 61. **Purple fluorite crystal, 1.8 cm, with calcite on matrix, from the Sub-Rosiclare level, Annabel Lee mine. Ross Lillie collection; Jeff Scovil photo.**

Figure 62. **Blue fluorite crystal group with calcite, 9.6 cm, from the Minerva #1 mine. Martin Zinn collection; Jeff Scovil photo.**

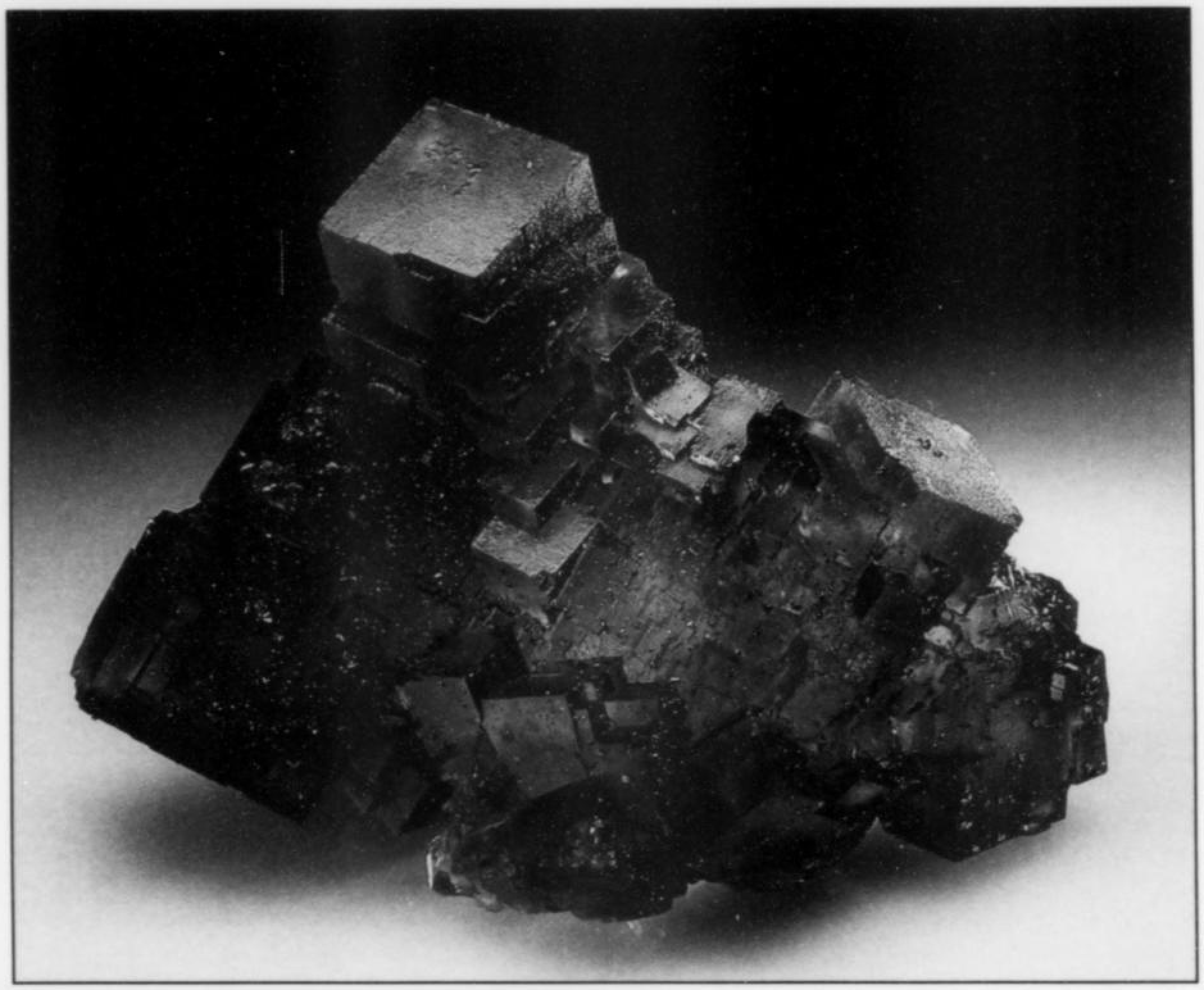


Figure 63. **Purple fluorite sprinkled with chalcopyrite microcrystals, 13.3 cm, from the Minerva #1 mine. Steven Neely collection; Jeff Scovil photo.**

Figure 64. **Pale purple fluorite on pale yellow fluorite, 7.8 cm, from the Cave in Rock area. Bannister collection, Harvard Mineralogical Museum #133853; Jeff Scovil photo.**

Figure 65. **Zoned colorless and purple fluorite crystal group on matrix, 7.8 cm, from the Minerva #1 mine. Ross Lillie collection; Jeff Scovil photo.**

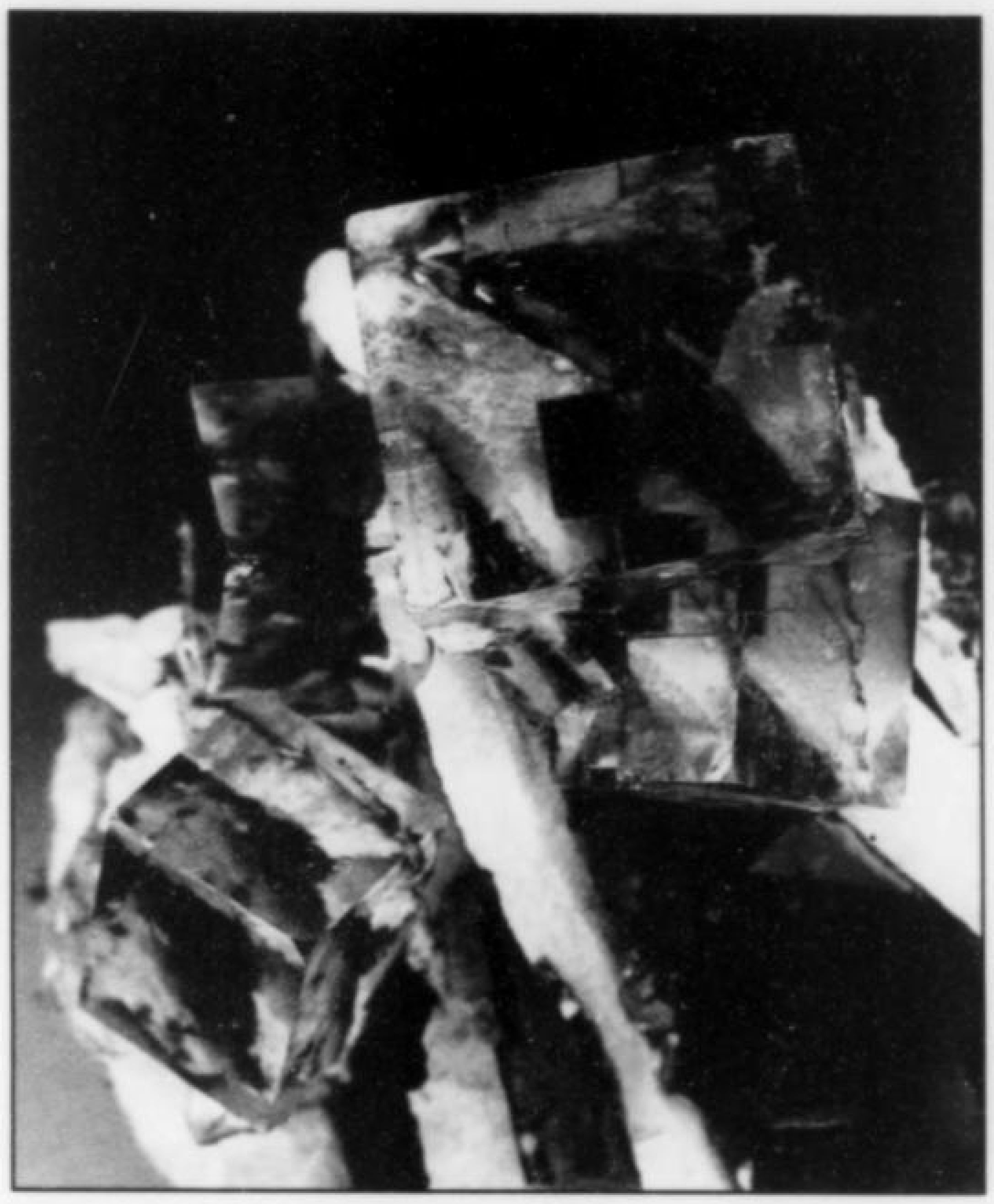


Figure 66. **Gemmy, pale purple fluorite crystals to 1.6 cm with dark purple central phantoms, on matrix, from the Rosiclare level of the Minerva #1 mine. Ross Lillie collection; Jeff Scovil photo.**

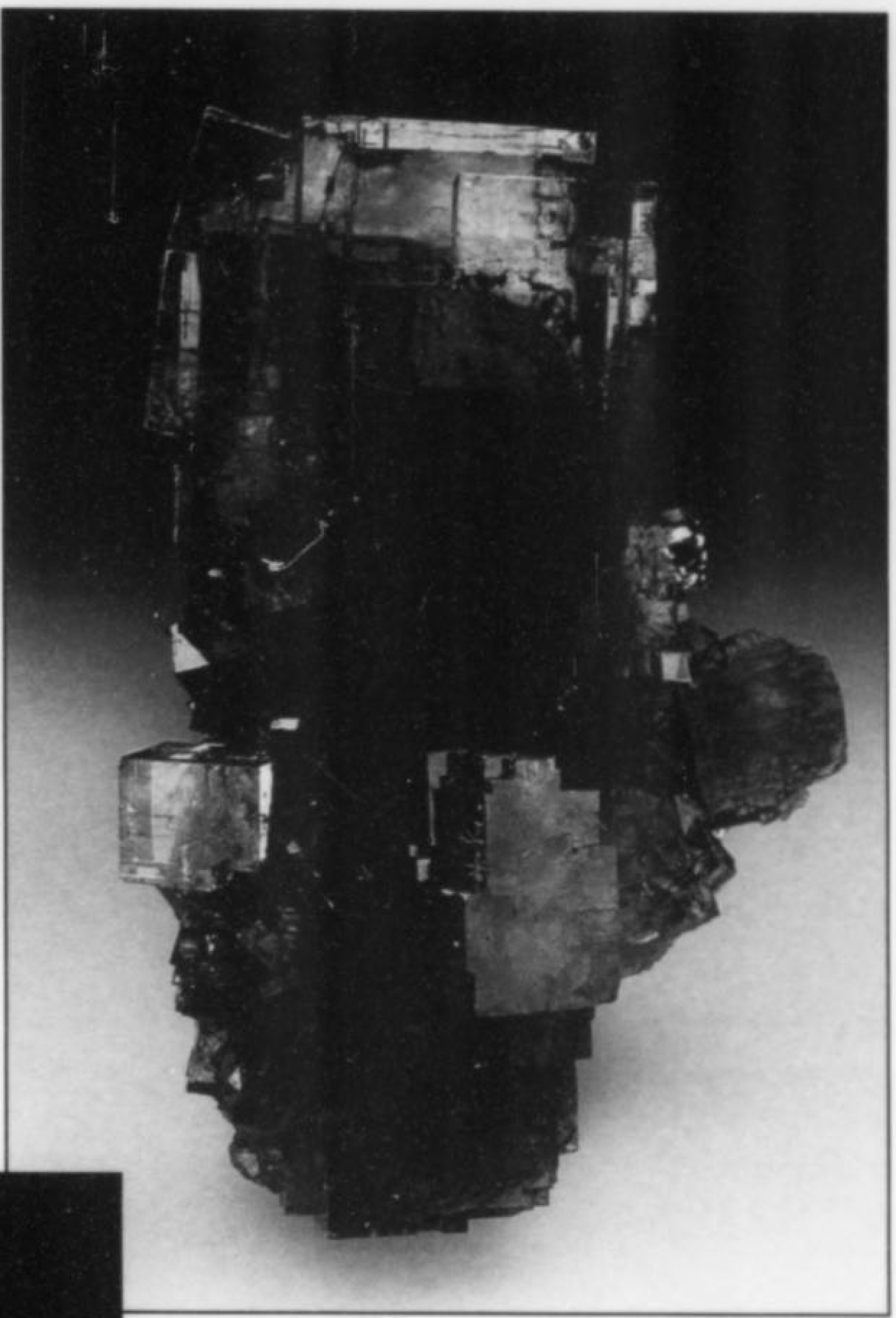


Figure 67. (above) **Color-zoned fluorite crystal group, 8.2 cm, from the Minerva #1 mine. William Severance collection; Jeff Scovil photo.**

Figure 68. (left) **Yellow fluorite crystal group, 11.7 cm, from the Mahoning #1 mine. Bannister collection, Harvard Mineralogical Museum #117446; Jeff Scovil photo.**

Figure 69. **Brilliant yellow fluorite crystal, 8.5 cm, from the Rosiclare level, Minerva #1 mine. Ross Lillie collection; Jeff Scovil photo.**

Figure 70. **Cuboctahedral galena on purple fluorite, 11 cm, from the Denton mine. William Severance collection; Jeff Scovil photo.**

Figure 71. **Cuboctahedral and cubic galena on purple fluorite, 6.1 cm, from the Denton mine. William Severance collection; Jeff Scovil photo.**

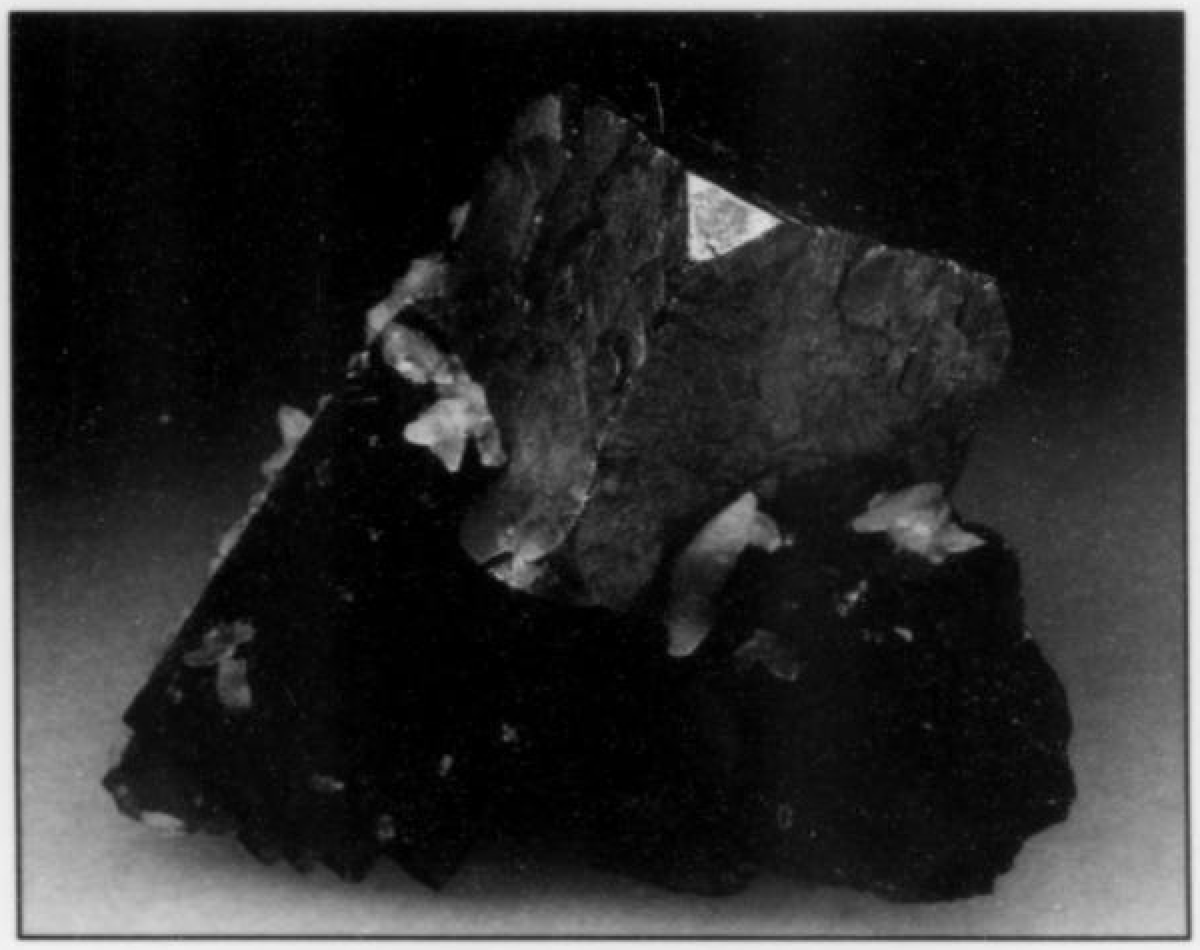
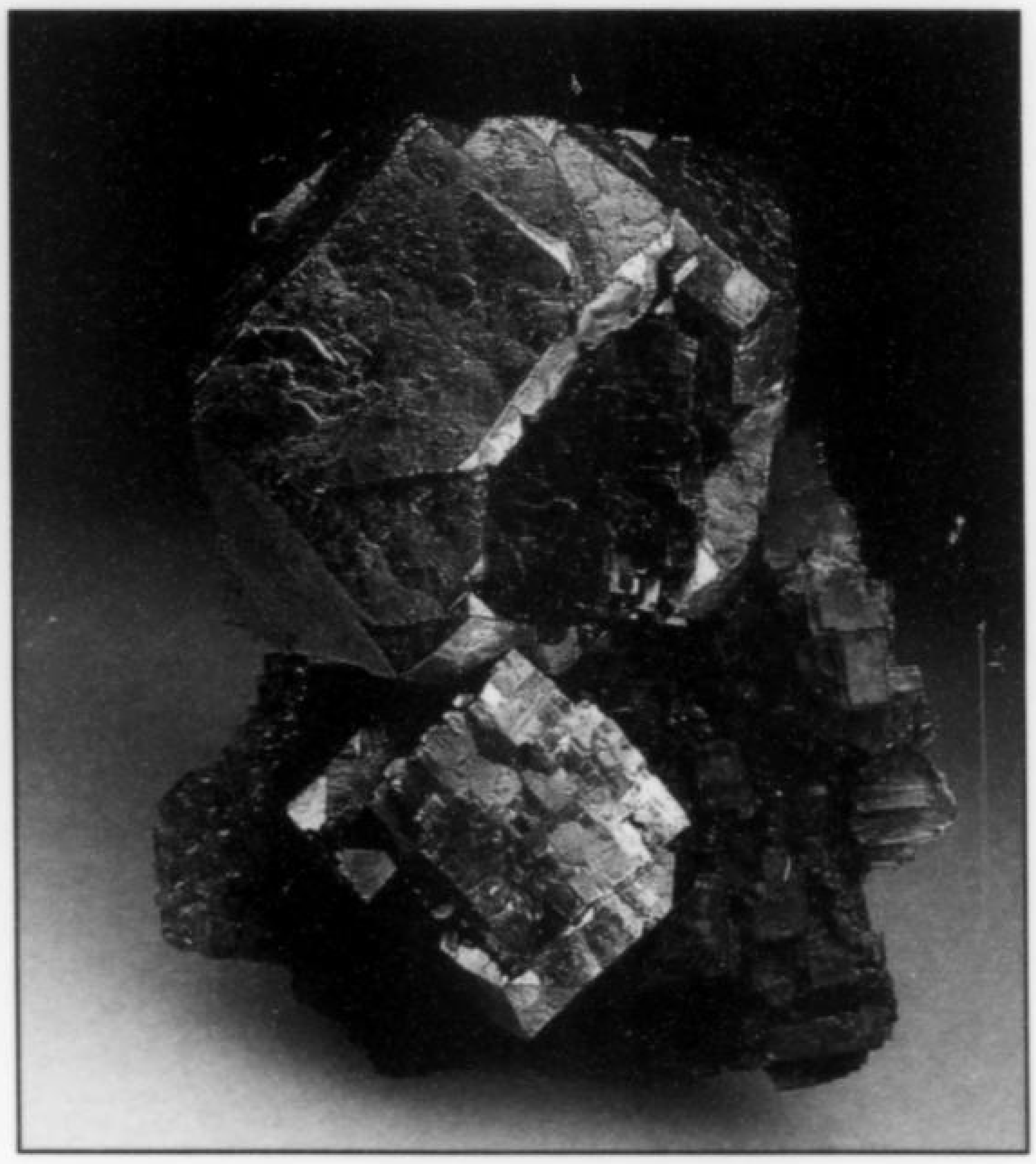


Figure 72. **Galena crystal with calcite on purple fluorite, 6.8 cm, from the Cave in Rock area. Martin Zinn collection; Jeff Scovil photo.**



Galena PbS

Galena occurs as cubic, cuboctahedral and octahedral crystals, and also as weathered, corroded masses. Galena in the district is slightly argentiferous, varying from 14 ounces of silver per ton at Hicks Dome to 2 or 3 ounces per ton in outlying deposits near Princeton, Kentucky. The galena at Cave in Rock contains about 6 ounces of silver per ton; Rosiclare galena typically contains twice that much.

Crystals of galena typically vary from 1 to 8 cm across, but the Annabel Lee and Denton mines have produced a few larger (30 cm) specimens. Galena associated with late-forming purple fluorite forms attractive specimens. Usually galena occurs disseminated as grains and cleavage masses with limestone, fluorite and sphalerite.

Galena has been reported in nearly every fluorite mine in the district. It tends to be less common in the larger barite deposits. The Davis-Deardorff mine contained an exceptionally large galena deposit (locally amounting to 10% of the ore), the crystals having an octahedral habit (Brecke, 1967).

Although lead was the economical ore of choice for the first 40 years of mining in the fluorite district, galena later became merely a by-product.

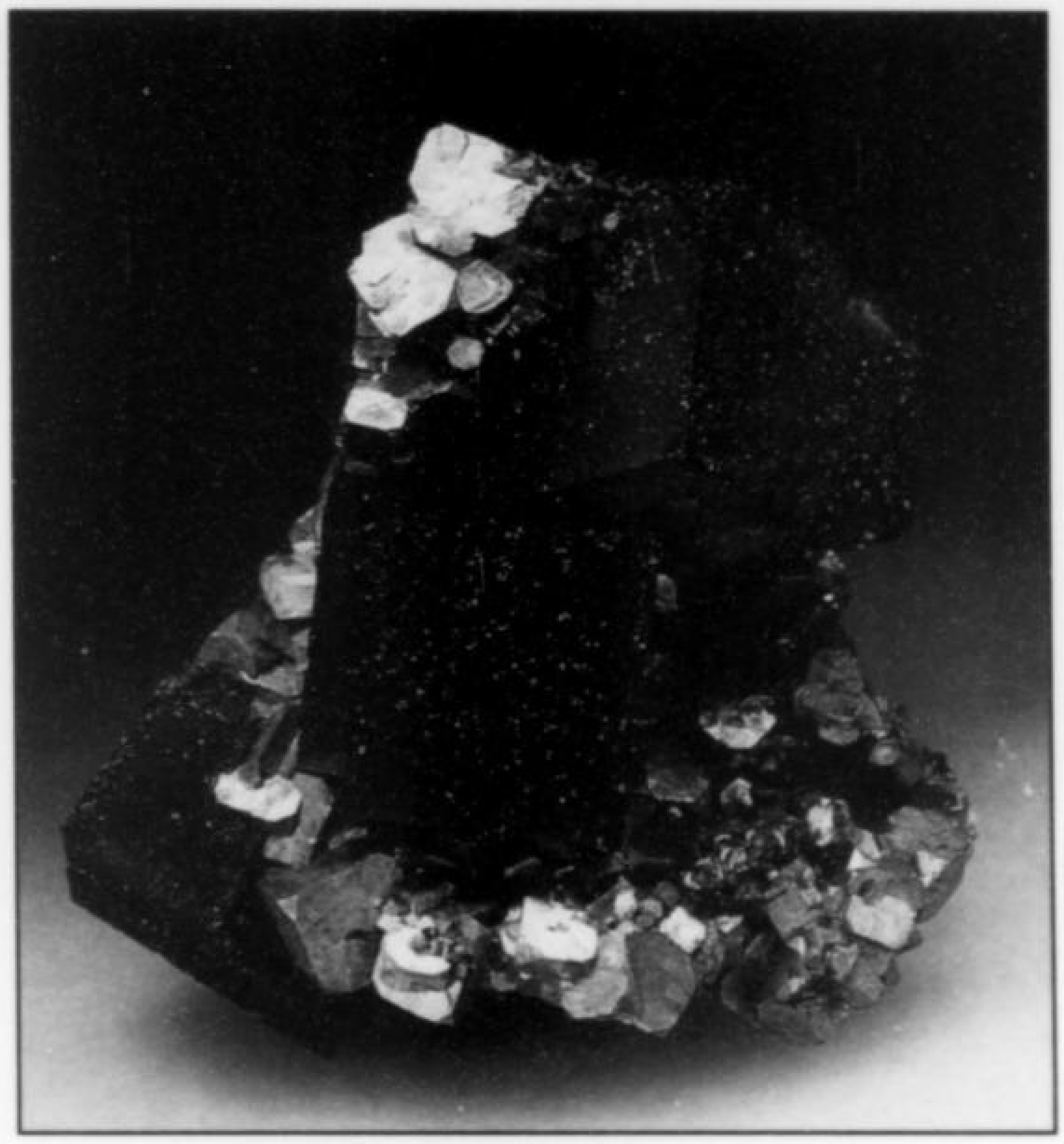


Figure 73. **Pyrite microcrystals on purple fluorite with galena and calcite, 10.5 cm, from the sub-Rosiclare level, Denton mine. Ross Lillie collection; Jeff Scovil photo.**

Greenockite CdS

Greenockite is a rare mineral in the district, occurring as a greenish yellow to orange-yellow crust on sphalerite. It also colors crystalline and botryoidal smithsonite. E. A. Brecke (1989, personal communication) observed that it can also stain calcite. Ulrich and Smith (1905) noted that its occurrence is widespread, wherever weathered sphalerite deposits are found. Despite this statement, greenockite is scarcely mentioned elsewhere in the literature. Brecke found greenockite as a film on the interior of vugs of sphalerite at the Red mine in the Empire district, Pope County, and at the Commodore mine in Kentucky. The writer has observed sphalerite with orange-yellow coatings but analyses have not been done to determine whether it is greenockite or some other alteration product.

Gypsum $CaSO_4 \cdot 2H_2O$

Gypsum has been described as an uncommon mineral in the district, having only been reported in good-sized crystals in pockets in the upper levels of the Hillside mine near Rosiclare (Bastin, 1931). This writer has found gypsum in druses coating fluorite and calcite at the old Austin lead mine at Spar Mountain, and in minute orange rosettes on chert at the Hickory Cane mine dump. Not mentioned previously in the literature was replacement of limestone by gypsum. A specimen from the Minerva No. 1 dump thought to be limestone and sphalerite was found, upon treatment with muriatic acid, to be substantially gypsum. E. A. Brecke (1989, personal communication) has found large crystals in vugs in limonite at the Klondike mine, Livingston County, Kentucky, and in the Guill mine north of Salem, Kentucky. Needle-like crystals up to 4 cm were observed on the 330-foot level of the Deardorff mine, Cave in Rock.

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Hemimorphite is a rare weathering product of sphalerite found in only a few mines in the district. Crystals occur in small, colorless, hemispherical and sheaf-like aggregates. Ulrich and Smith (1905) reported hemimorphite from the Hodge and Evening Star mines and the Clement shaft (all in Kentucky). The writer has found aggregates of hemimorphite in 1-mm clusters with cerussite on galena on the dump of the Rock shaft, Hickory Cane mine.

Hydrozincite $Zn_5(CO_3)_2(OH)_6$

Hydrozincite is, like hemimorphite, a weathering product of sphalerite and is very rare in the district. Ulrich and Smith (1905) report it as a white, dull, fibrous incrustation associated with smithsonite. It sometimes occurs mixed with smithsonite. Hydrozincite was only reported in sizable quantities at the Old Jim mine. It has been found sparingly at the Drescher open cut mine. This mineral probably can be found in small amounts at other zinc mines, but has not been reported from Illinois.

Kaolinite $Al_2Si_2O_5(OH)_4$

Kaolinite was noted by Ulrich and Smith (1905) as a white to cream-colored, very fine-grained aggregate, sometimes with a tinge of red. It has been found at the Asbridge mine and the No. 6 shaft of the Blue and Marble mine (both on the Tabb fault system) as "patches in clay adjacent to fluorite veins." It also occurs in minute particles in the red clays of other Kentucky mines. Bain (1905) reported evidence of a large body of kaolin removed from near the Pittsburg mine in Illinois. At that time the "Old Clay Pit" had been abandoned for over 50 years.

Limonite hydrous Fe oxides

Limonite is a common weathering product of decomposing marcasite and pyrite in clays and (rarely) in areas adjacent to veins, as dark brownish masses. Bastin (1931) suggests limonite is pseudomorphic after siderite because traces of rhombic form and cleavage faces persist. Limonite has been found with the barite deposits at Spar Mountain, as stalactitic forms in the Stewart and Hillside mines, and as botryoidal masses at Conn's mine. Bain (1905) mentions an early abundance of limonite which lead to the erection of the Martha iron furnace and the Illinois iron furnace. Limonite occurs intimately admixed in the Rosiclare Sandstone at the Green-Defender mines at Spar Mountain.

Malachite $Cu_2CO_3(OH)_2$

Malachite forms as a weathering product of chalcopyrite, sometimes with cuprite. It commonly occurs as films or crusts and rarely as acicular sprays, and as pseudomorphs after chalcopyrite. Ulrich and Smith (1905) note an occurrence in the Wilson copper shaft (Kentucky). The writer has found malachite at many mine dumps, including the Minerva No. 1 (with azurite), the Annie L No. 45 shaft, the Henson mine (as inclusions in fluorite), Conn's mine, and in barite at Spar Mountain. Bain (1905) noted it as a greenish stain, particularly at the so-called "copper vein" near Elizabethtown. Bastin (1931) reported malachite being found sparingly in the Rosiclare area. Heyl (1989, personal communication) reports it as coatings on chalcopyrite at the Rose mine. E. A. Brecke (1989, personal communication) noted malachite in *all* of the shallow mines in the Cave in Rock district, especially at Lead Hill. In addition, an interesting occurrence was found in the Indiana mine. It consisted of small groups of bright green acicular crystals in vugs in vein calcite. It forms rapidly and is abundant in the parking lot of the Rosiclare Lead and Spar Company mill site.

Marcasite FeS_2

Early writers made little distinction between marcasite and pyrite occurrences. Weller *et al.* (1952) noted pyrite as being the dominant iron sulfide, whereas Brecke (1967) called marcasite more common than either pyrite or chalcopyrite. Oesterling (1952)

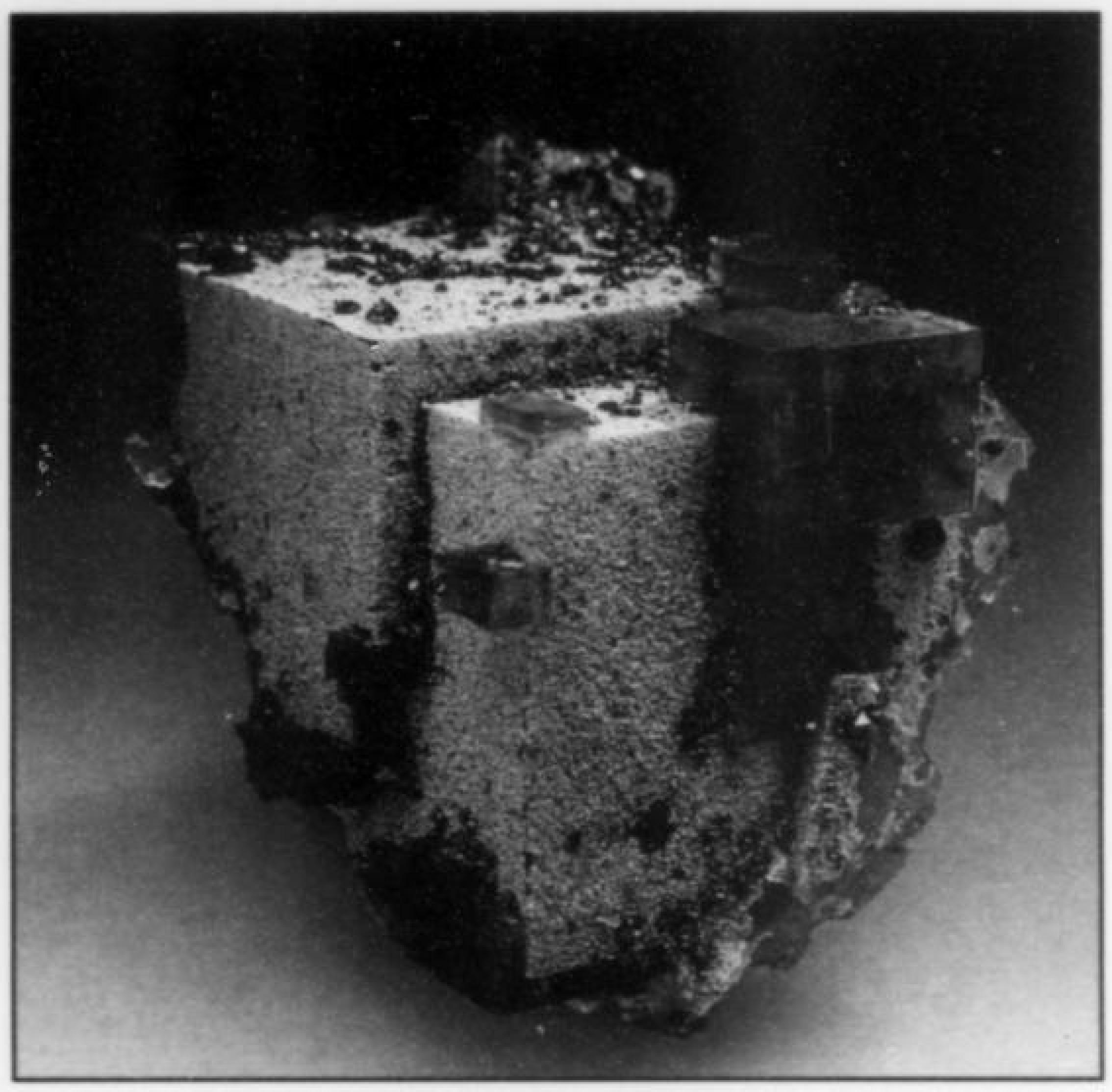


Figure 74. **Second-generation purple fluorite with marcasite on white (quartz?) coated fluorite, 8.4 cm, from the Rosiclare level of the Denton mine. Ross Lillie collection; Jeff Scovil photo.**

observed quantities of marcasite with the sphalerite at the Hutson mine in Kentucky.

Two generations of marcasite have been identified. The first formed simultaneously with fluorite and is found as inclusions. The second generation formed at the end of the mineralization period and is associated with scalenohedral calcite and barite. It occurs as crusts, stalactites and as a cementing material in brecciated fluorite (Brecke, 1967). Both the Henson and Annabel Lee mines have produced beautiful wiry overgrowths and spear-shaped crystals (Lillie, 1988). Marcasite is common on the dumps of the Henson mine.

Paralstonite $BaCa(CO_3)_2$

Paralstonite was reported by Robbins (1988) from the Minerva No. 1 mine. Thomas Bee (1988, personal communication) reported that the mineral had been identified by X-ray diffraction by a European mineral dealer. A specimen he provided was tested by Dr. George Lager, University of Louisville, using a Guinier X-ray diffraction camera, and its identity was confirmed. Other specimens were identified by their orange fluorescence under shortwave ultraviolet light (distinguishing it from alstonite). Paralstonite has also been found at the Annabel Lee mine, on yellow fluorite (Harvard specimen).

Pyrite FeS_2

Pyrite occurs as disseminated grains throughout the district. A concentration of pyrite was found replacing a 15 to 30-cm bed of limestone at the Old Jim mine, possibly directly associated with the lamprophyre dike at this exposure (Ulrich and Smith, 1905). Bastin (1931) reported pyrite at the Hillside mine, both as inclusions and as overgrowths on fluorite. In a wall of the Argo vein, Bastin reported a cavity 60 feet long, 30 feet high and 15 feet wide which was lined with pyrite of radiating structure, overlain by calcite and a second layer of pyrite. A second, larger cavity reported in the

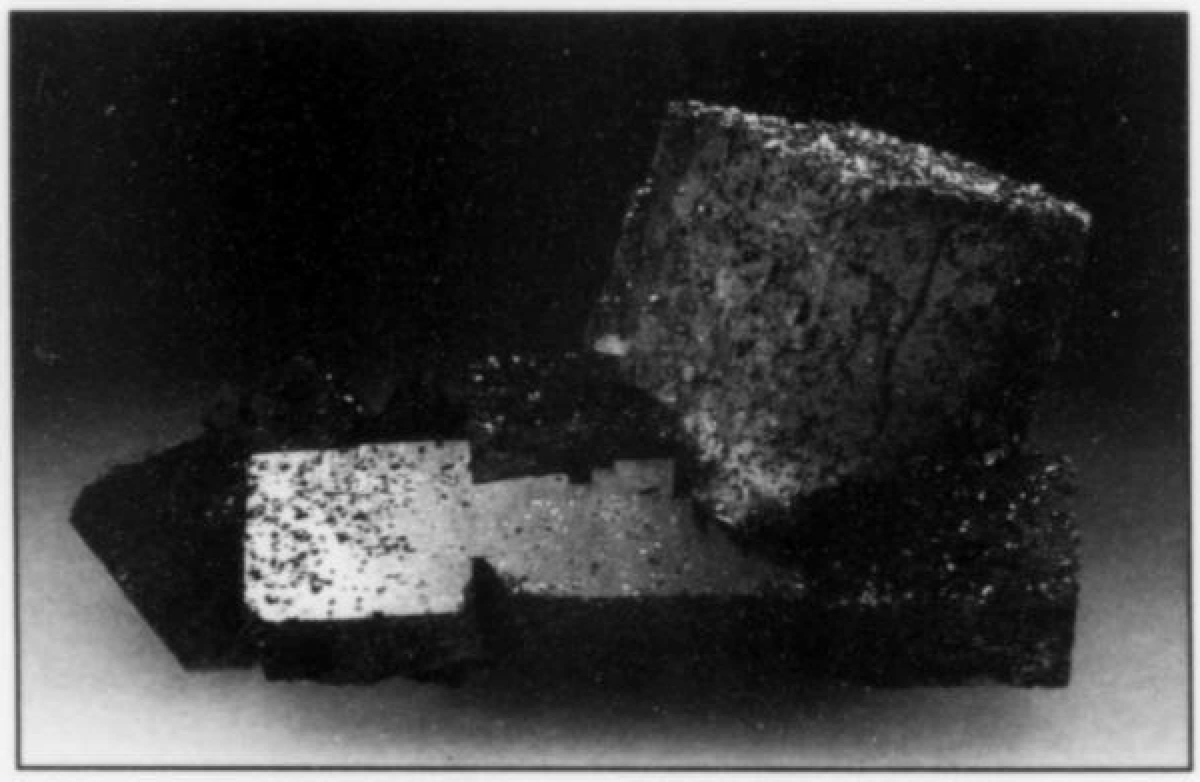


Figure 75. **Pyrite microcrystals sprinkled on yellow and purple fluorite, 7.3 cm, from the Minerva #1 mine. Martin Zinn collection; Jeff Scovil photo.**

Figure 76. **Paralstonite (white) with yellow fluorite, 13.2 cm, from the Annabel Lee mine. Harvard collection #134024; Jeff Scovil photo.**

Argo mine had 1-cm-thick crusts of pyrite with calcite crystals. Fluorite was not associated in either pocket. The Fairview-Rosiclare vein dumps contained pyrite stalactites, possibly from similar cavities. Worm-like overgrowths over yellow fluorite have also been reported from the Annabel Lee mine (Lillie, 1988).

Pyromorphite $Pb_5(PO_4)_3Cl$

Pyromorphite is a relatively rare weathering product of galena. It occurs in tiny to microscopic translucent green crystals, both singly and in aggregates. Ulrich and Smith (1905) noted small quantities on fluorite from the Tabor and Wheeler mines, and fluorite druses at the Kentucky No. 4 shaft. Brecke (1967) reported pyromorphite in well-developed crystals in small vugs and fractures in chert at the Patrick lead mine. He described a doubly terminated 2-mm crystal in an internal cast of a brachiopod in chert (1989, personal communication). Brecke also notes specimens from the Lacy mine, a little shaft on the south slope of Hicks Dome and near the Davenport mine in Kentucky. That specimen was found on an old dump on the main fault foot wall. The Davenport mine was very deeply oxidized; soft ground was mined to a depth of 320 feet. Pyromorphite was reported in a large sheet at Spar Mountain (Dick Atwood, 1989, personal communication). It has also been found by this writer in microscopic apple-green crystals associated with glassy cerussite crystals, corroded galena, quartz and tetrahexahedral purple fluorite from a single sandstone boulder on the dump of the Rosiclare Lead and Spar Company mill.

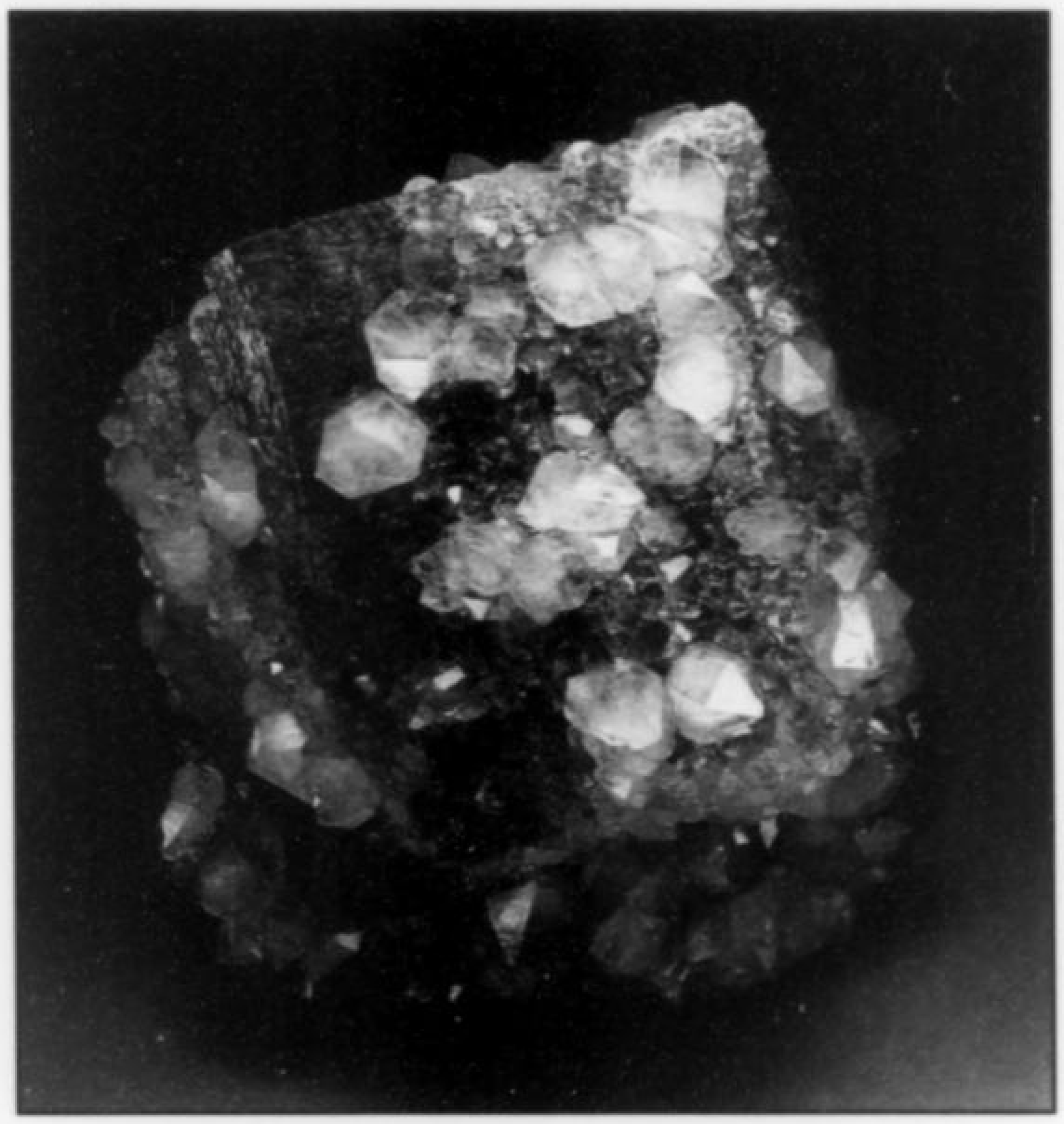


Figure 78. **Equant quartz crystals coating a yellow fluorite crystal, 14.6 cm, from the Deardorff mine. Harvard collection #117471; Jeff Scovil photo.**

Quartz SiO_2

Quartz crystals are usually very small, found in druses on wall rock and in fractures (especially where the matrix is sandstone). Forming late in the mineralization sequence, it is occasionally found coating fluorite, galena and calcite. Bastin (1931) reported crystals up to 6 mm at the Hillside mine dump. Brecke (1962) noted silicification at the Davis-Deardorff mine, in places developing a banded structure. Crystals up to 2.5 cm were found associated with pale purple fluorite, galena and sphalerite (Lillie, 1988).

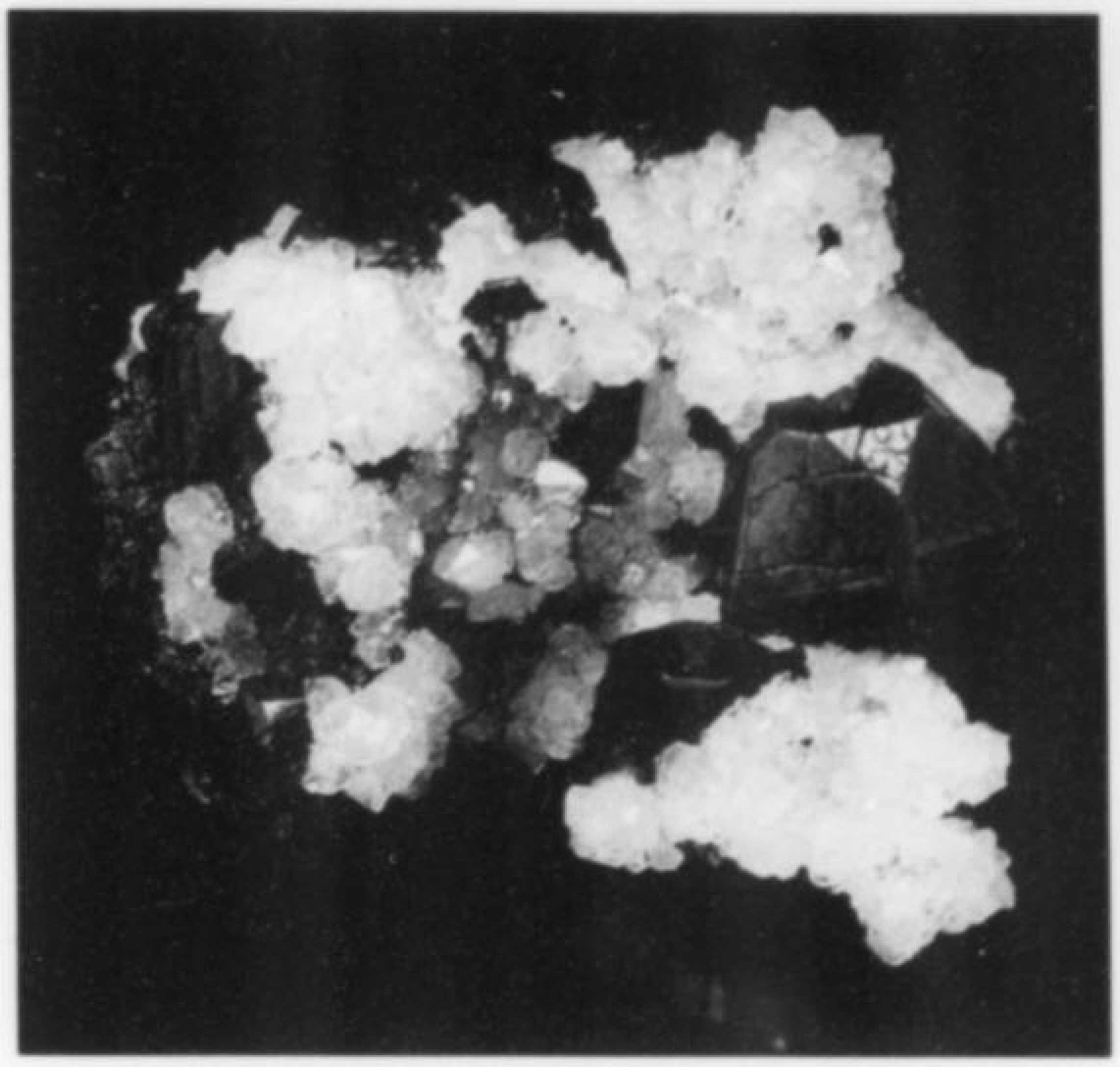


Figure 77. **White quartz on black sphalerite crystal group, 8.6 cm, from the Deardorff mine. Steven Neely collection; Jeff Scovil photo.**

Highly acicular, doubly terminated quartz crystals (0.1 x 3 mm) occur as inclusions and as overgrowths on purple fluorite at Conn's mine. Crystals are abundant in the residual soil around excavated vein deposits. Quartz is not especially abundant in the district as a whole, but is significant in local concentrations.

Quartz often carries petroleum inclusions which give it a smoky color. This "smoky" quartz has been mentioned rarely in the literature. Bain (1905) described jet-black quartz; Bastin (1931) mentioned brownish quartz; Brecke (1967) noted smoky quartz from the Hill mine. The writer has collected smoky quartz from the dumps of the Minerva No. 1 and Hickory Cane mines and smoky quartz in calcite at the Rosiclare mill site. The largest crystals are about 6 mm long. In addition to the smoky color, the petroleum inclusions cause the quartz to be exceptionally fluorescent.

Siderite $FeCO_3$

Unaltered siderite has never been reported from the district, but Bastin (1931) suspected it to be the progenitor of rhombic limonite pseudomorphs. (Ferroan dolomite might also have produced such pseudomorphs.) Richardson and Pinckney (1984) list it in the paragenetic sequence without discussion.

Smithsonite $ZnCO_3$

Smithsonite occurred as locally common deposits early in the history of mining in the district. It is now quite rare, as virtually all known near-surface zinc deposits have been mined out.

At the Old Jim mine, smithsonite was the chief constituent of the ore, with only minor amounts of sphalerite. At the Hutson mine, a sizable deposit of sphalerite was found beneath a 50 to 75-foot-thick mantle of smithsonite. It has been reported rarely in crystals, but is generally in a massive form. Ulrich and Smith (1905) note:

> Crystals are generally light colored and translucent; they are always small, found singly and in aggregates on the walls of cavities, and are usually short rhombohedral, with curved rough faces. They also occur doubly terminated, spindle-shaped, and with club-shaped terminals, frequently aggregated in masses. Reniform, botryoidal and stalactitic aggregates are more common in cavities in the more massive granular varieties.

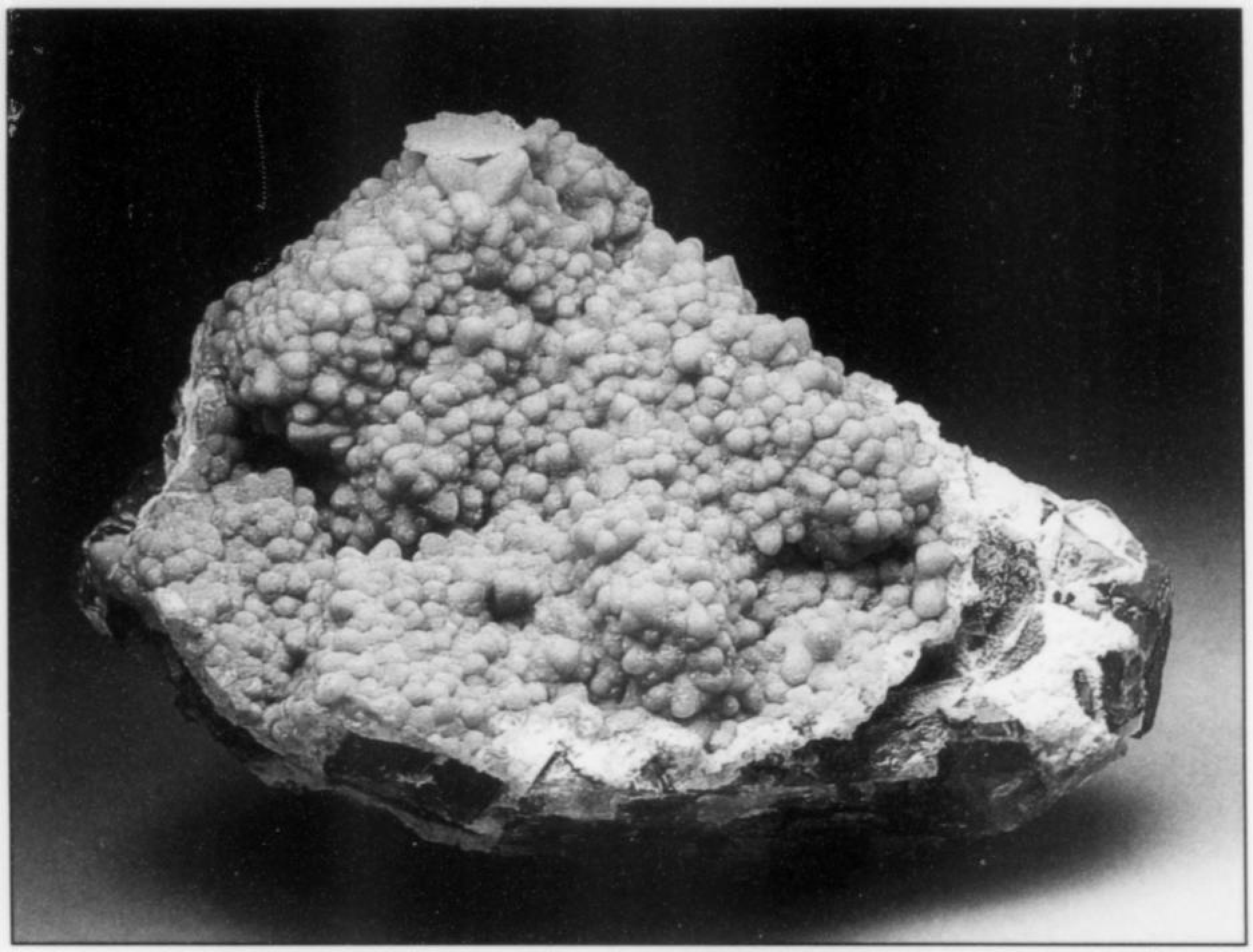


Figure 79. **Smithsonite crystal crust colored yellow by greenockite, on purple fluorite, 15 cm, from the Hill lead mine, Hardin County. Harvard collection #133880; Jeff Scovil photo.**

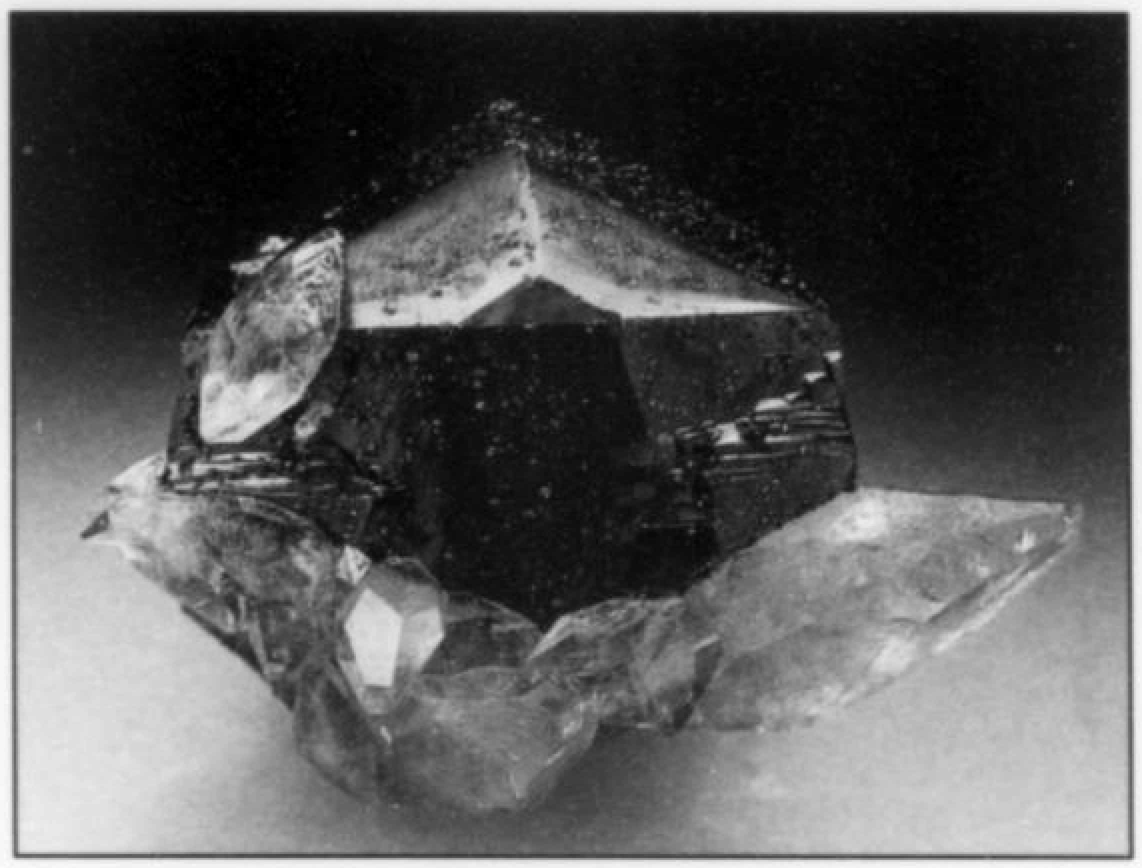


Figure 80. **Pyrite microcrystals on sphalerite with calcite, 5 cm, from the Rosiclare level, Denton mine. Ross Lillie collection; Jeff Scovil photo.**

Smithsonite replacing limestone is dark gray in color with a granular texture. Bain (1905) described it as "rusty-looking material, not unlike some of the weathered chert in appearance, but distinguished by its weight." Where greenockite occurs with smithsonite, it appears as the well-known yellow "turkey fat" variety. The most significant smithsonite deposits historically include the Old Jim, Hutson, Commodore, Mann-McDowell, Lady Farmer and Hickory Cane mines in Kentucky and the Patrick lead mine in Illinois. Bain (1905) reported smithsonite from the Empire district, though not in economic quantities. E. A. Brecke (1989, personal communication) noted smithsonite in the shallower part of the A. L. Davis mine in the Cave in Rock district. Smithsonite can still be collected at the Old Jim mine, with travertine.

Sphalerite ZnS

Sphalerite occurs throughout the district as a common sulfide. It is found in both vein-type and bedding replacement deposits. Unlike galena, sphalerite has been mined as a primary ore. In Kentucky, the Hutson mine was the largest producer. The Davis-Deardorff and the Minerva No. 1 were major producers in Illinois. Beautiful crystals up to 2 cm in size were common over the feeding faults in the Deardorff (A. V. Heyl, 1989, personal communication). In fact, during times when the demand for fluorite was low, mines concentrated on the zinc-rich areas to maintain profitability (G. Montgomery, personal communication). Despite the quantity of zinc at these two Illinois mines, sphalerite was subordinate to fluorite in relative abundance. The Old Jim and Hutson mines had only non-economic quantities of fluorite.

Sphalerite occurs as crystals and crystal aggregates in colors ranging from yellow to red to black, and also as disseminated grains. Sphalerite in the district is enriched with cadmium, germanium and traces of gallium. Fluorite and sphalerite in alternating bands were reported from the Cullen mine near Salem, Kentucky. Sphalerite crystals up to 4 cm across can be found in massive rhythmite barite on the dumps of the Minerva No. 1 mine. In fact, sphalerite can be found on many mine dumps in the district, attesting to its abundance. In the south orebody of the Annabel Lee mine, sphalerite beds form a layer resembling sandstone several feet in thickness. The sphalerite is associated with galena and dark purple fluorite. The luster of sphalerite varies from adamantine to submetallic. Richardson and Pinckney (1984) noted that sphalerite from the Deardorff mine showed internal sector zoning (not continuous banding) in cross-section. The interior of the crystals tends to be darker than the exterior layers.

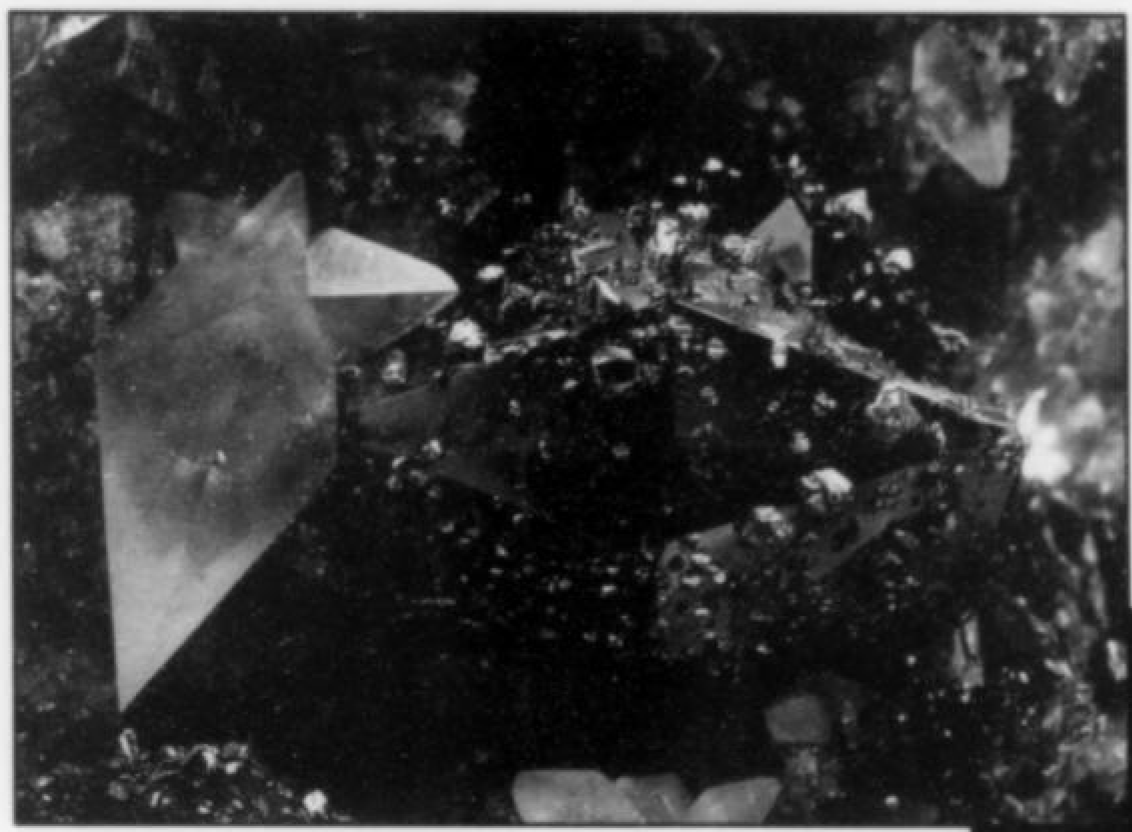


Figure 81. **Pyrite microcrystals on black sphalerite crystal (2.2 cm) with calcite and purple fluorite, from the Rosiclare level of the Denton mine. Ross Lillie collection; Jeff Scovil photo.**

Figure 82. **Pale yellow calcite with black sphalerite on purple fluorite, 7.5 cm, from the Minerva #1 mine. Martin Zinn collection; Jeff Scovil photo.**

Stibnite SbS_2

Stibnite was reported by Bain (1905) and Currier (1923) in the Fairview mine in Rosiclare. Neither actually saw the purported specimen, however, nor did they find additional specimens either in Illinois or Kentucky. Bain also mentions a specimen considered to be jamesonite from a Mr. Eilers, also from the Fairview mine. Both species remain unconfirmed.

Strontianite $SrCO_3$

Strontianite is a rare mineral that has been reported from several mines in the Illinois portion of the district, including the Henson, Minerva No. 1, West Green, and West Vein mines. Crystals typically form radiating spheres or bow-ties. Colors range from white to pink and brown. Associated minerals include barite and fluorite from the Minerva No. 1 and West Green mines, stalactitic marcasite from the Henson mine, and scalenohedral calcite from the West Vein mine (Lillie, 1988).

Sulfur S

Sulfur was reported by Ulrich and Smith (1905) at the Brown and Kentucky No. 4 mines, as yellow crystals in partially weathered galena. Brecke (1967) noted occurrences of sulfur (with gypsum) in the Edgar Davis mine after the removal of H_2S-charged water. It apparently precipitated out on the walls during low-oxygen conditions. The writer has observed very small quantities of sulfur in the Victory mines, as yellow smears consisting of minute grains, and as crystals on brown calcite in cores at the Victory mill dump.

Vaesite NiS_2

Vaesite was reported in microscopic grains at the W. L. Davis-Deardorff mine, with pyrite and nickeloan pyrite in the "coon-tail" ore in alternating beds of fluorite and sphalerite (Park, 1967).

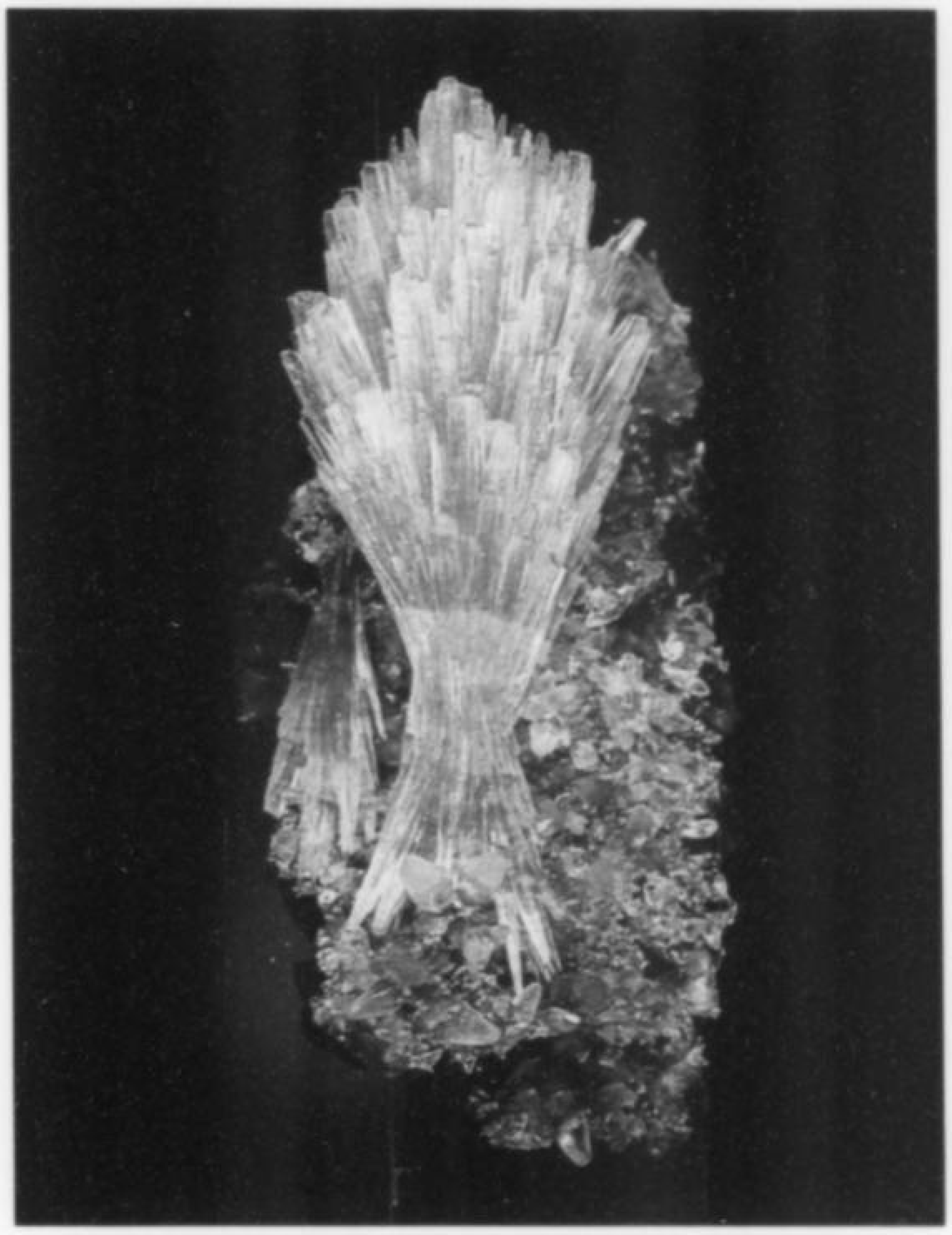


Figure 83. **Strontianite crystal bundle with calcite on purple fluorite, 5.9 cm, from the Minerva #1 mine. Steven Neely collection; Jeff Scovil photo.**

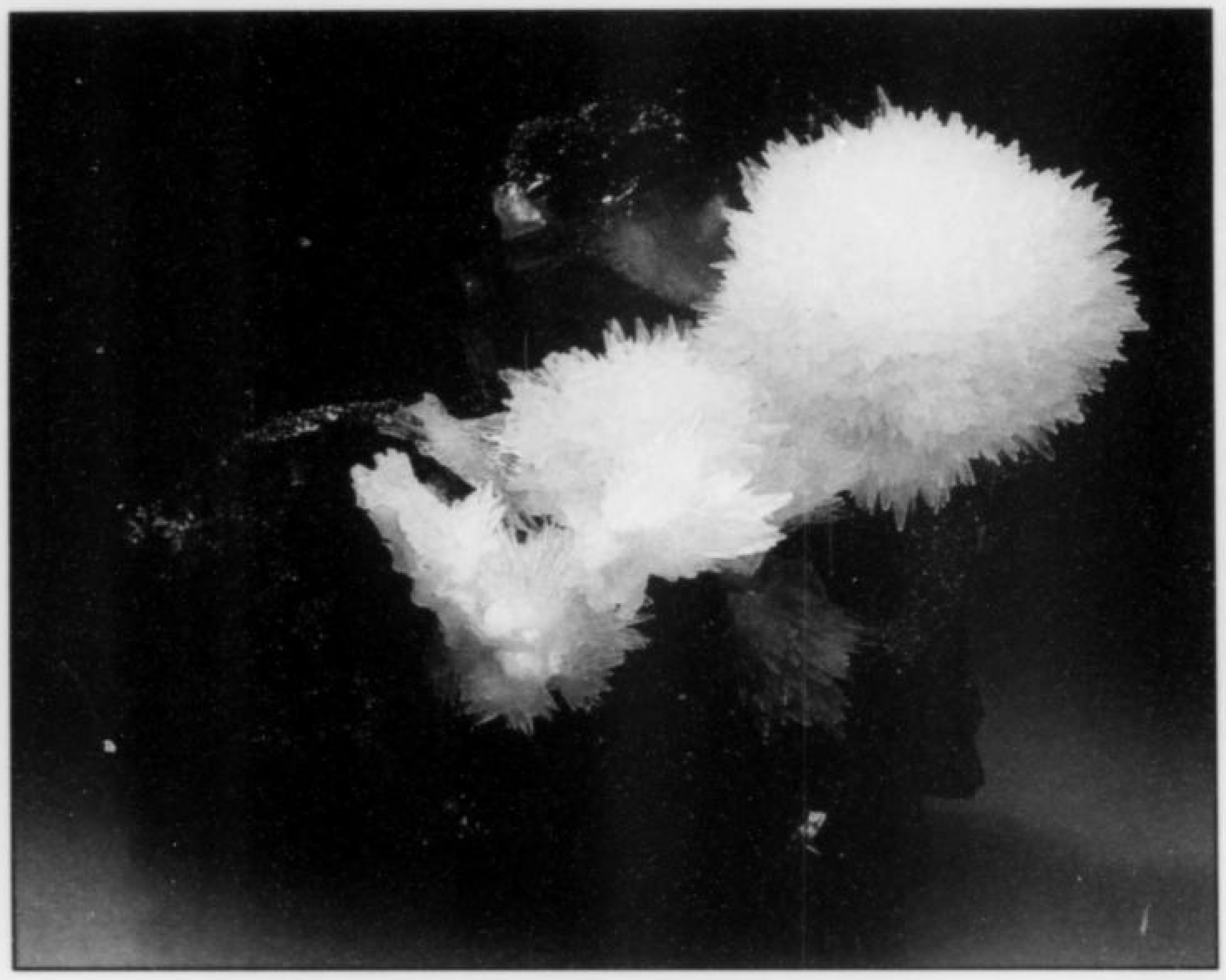


Figure 84. **White strontianite on fluorite and sphalerite, 15 cm, from the Bethel level of the Minerva #1 mine. Ross Lillie collection; Jeff Scovil photo.**

Figure 85. **Acicular strontianite on fluorite, 9 cm, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #124613; Jeff Scovil photo.**

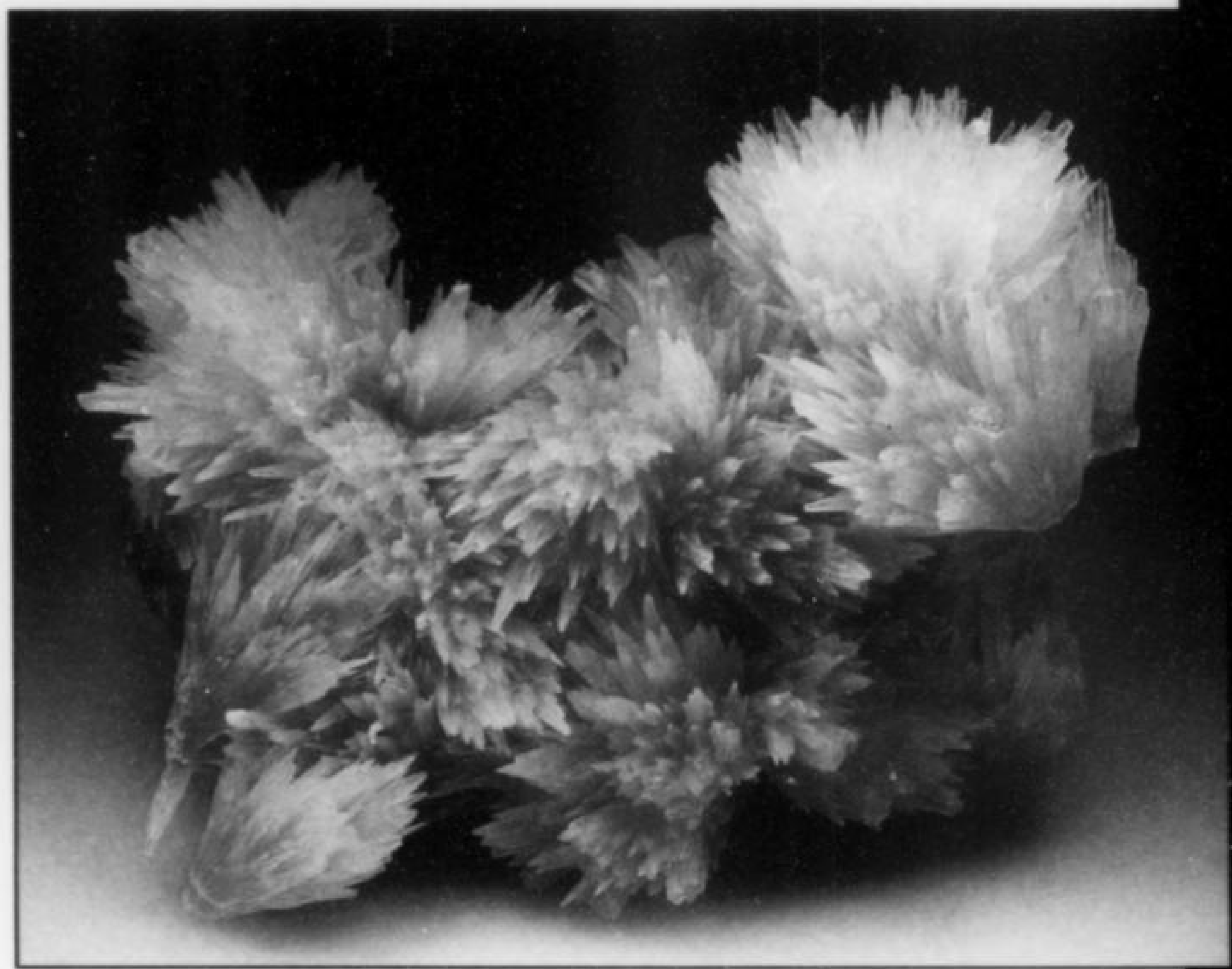


Figure 86. **Strontianite crystal group, 13.7 cm, from the Rosiclare level, Minerva #1 mine. Jeff Scovil photo.**

Wad Mn oxides

Wad occurs in disseminated grains, scattered in clay and occasionally with barite. Ulrich and Smith (1905) noted an abundance of wad at the Givens mine in Kentucky. Analysis indicated wad from this locality contained 2% to 17% cobalt and nickel. The writer has observed wad with quartz and chalcopyrite from the dump of the Minerva No. 1 mine, and with galena at Conn's mine.

Witherite $BaCO_3$

Witherite is an alteration product of barite which has been found at the Minerva No. 1, West Green, and Ozark-Mahoning No. 1

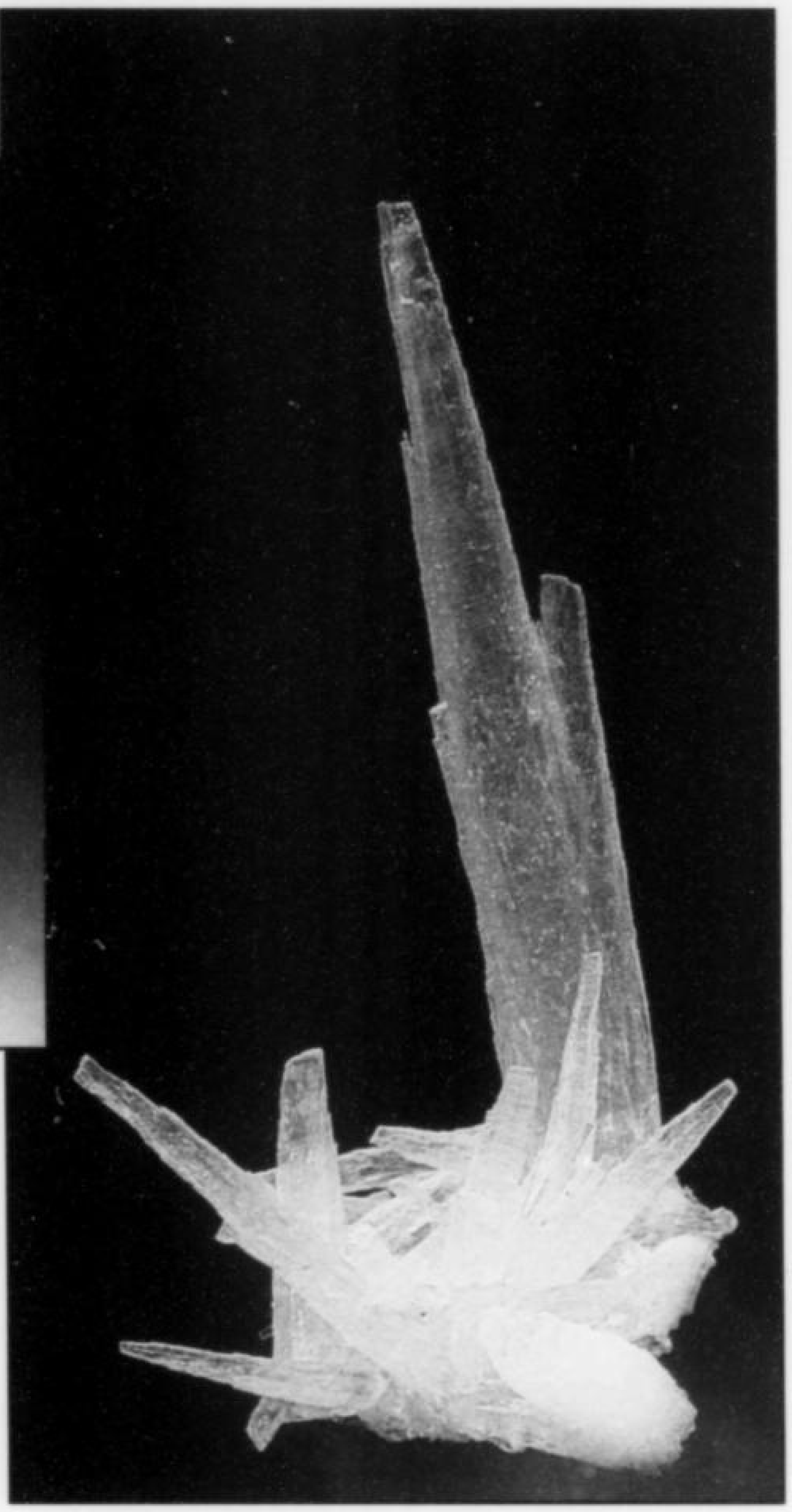


Figure 87. **Strontianite crystal group, 5.2 cm, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #117133; Jeff Scovil photo.**

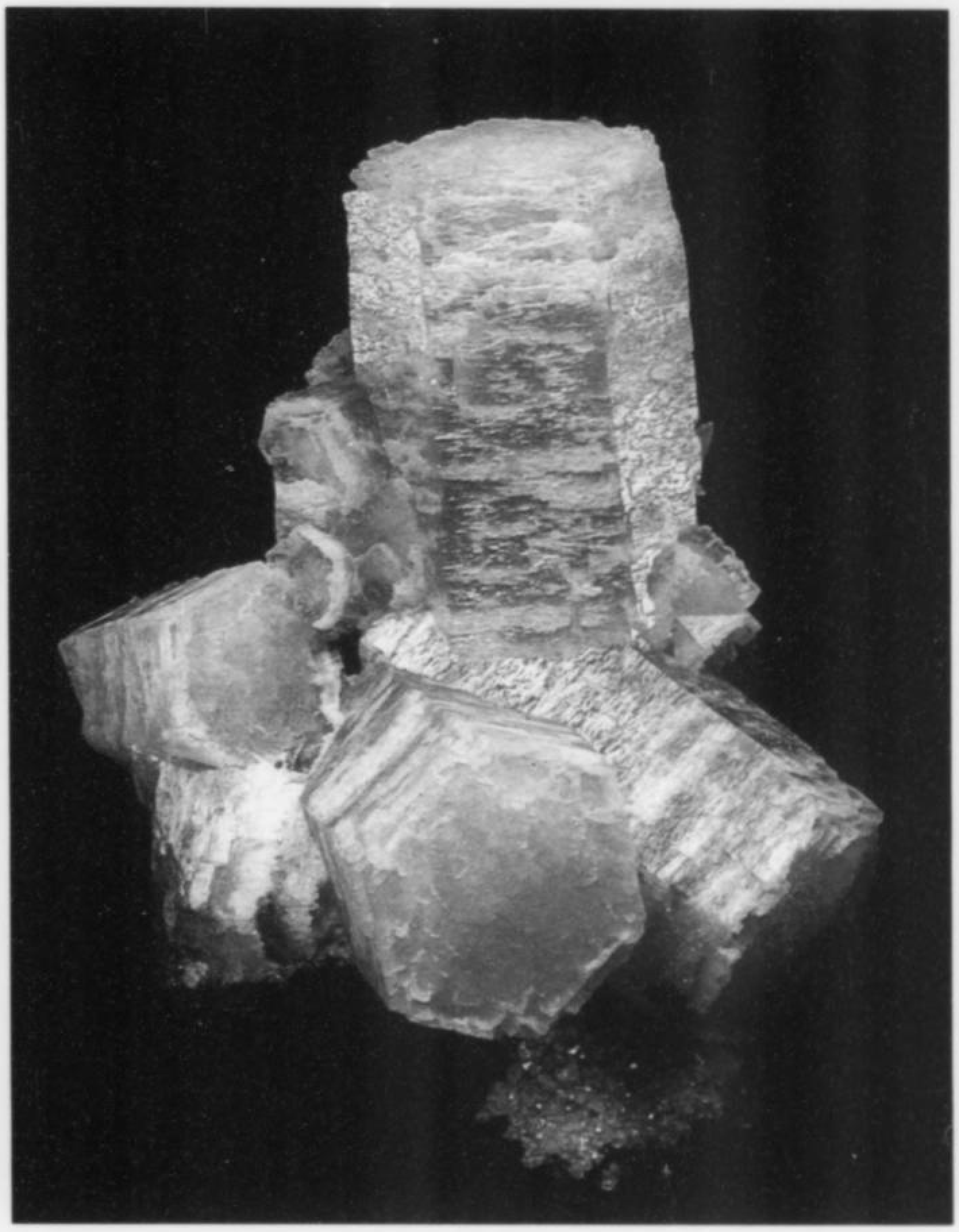
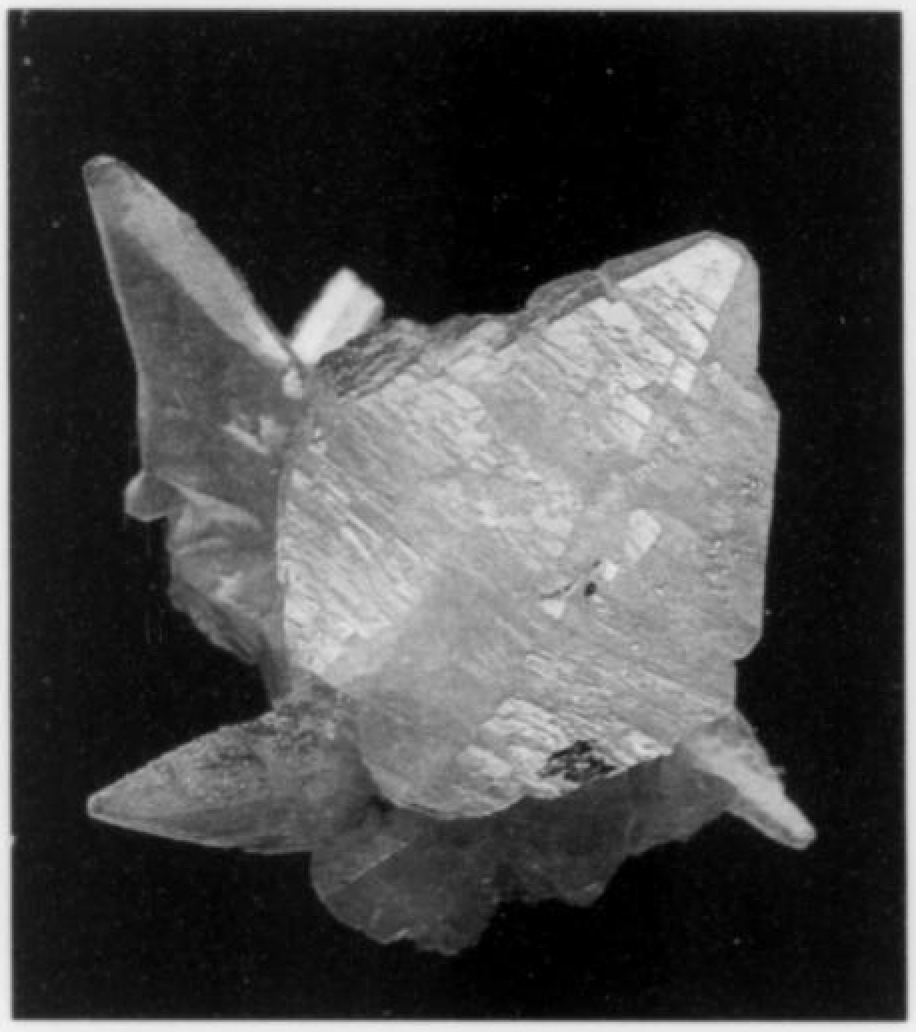


Figure 88. **Witherite crystal group, 10.6 cm, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #117436; Jeff Scovil photo.**

Figure 89. **Witherite crystal, 3.5 cm, on calcite, from the Minerva #1 mine. Bannister collection, Harvard Mineralogical Museum #126260; Jeff Scovil photo.**



mines. Crystals are orthorhombic, but appear hexagonal due to repeated twinning on (110). Francis (1982) noted steep dipyramids as being less common than prismatic crystals, terminated by very shallow dipyramids resembling the basal pinacoid, or by cavernous hopper-like ends. Witherite may also occur as spherical or drusy (botryoidal) masses on limestone, barite, calcite and (often etched) fluorite. Crystals as large as 12 cm have been found (Lillie, 1988), but most are smaller; the color is generally gray to white, occasionally with a yellowish tinge. Witherite is strongly fluorescent under longwave ultraviolet light.

CURRENT CONDITIONS

Fluorite mining is no longer taking place in the district. Up until recently there were three major operating mines, all owned by the Ozark-Mahoning Company: the Denton mine (which operated the longest), the Annabel Lee mine, and the Minerva No. 1 mine, now called Ozark-Mahoning No. 1 mine. The Ozark-Mahoning Company operated a mill in Rosiclare with much of their ore being utilized in the production of anhydrous hydrofluoric acid (Evans and Hellier, 1986).

The Henson mine, operated by Ozark-Mahoning, was closed in 1986 due to ore depletion (G. Montgomery, personal communication). Fluorite from this vein deposit was massive and typically deep purple. Compared to other mines, there were relatively few collector specimens recovered owing to the non-vuggy nature of the deposit.

For several years the Inverness Mining Company operated a drying mill at the Minerva No. 1 mine site. Fluorite was imported from South Africa and China to be processed here, until Ozark-Mahoning purchased the property.

Marathon Oil Company, a subsidiary of USX (formerly U.S. Steel Corporation) owns the Babb-Barnes mine and mill near Salem, Kentucky, including a large acreage of favorable land where core drilling has been done in recent years. Several large orebodies, not yet developed, are reported to exist there.

Other substantial drilled reserves in Kentucky are owned by Reynolds Aluminum, Armco Steel, and Ozark-Mahoning. All of these companies have conducted extensive drilling projects in recent years and own the mineral rights (G. Montgomery, personal communication).

Ozark-Mahoning Company has no plans to reopen any mines or do extensive exploration. According to Eric Livingston, Ozark-Mahoning Company geologist, China contains major vein deposits of fluorite located near the east coast that account for 70% of the world's fluorite production. Abundant ore, labor, and convenient shipping provide the lowest cost supply. Livingston compares China's reserves today to those of the United States at the beginning of this century. Currently much of the fluorite from China is sent to Mexico, where it is processed into hydrofluoric acid. Many of Mexico's mines are on "standby" because they cannot operate as cheaply as the Chinese. In addition, arsenic-bearing Mexican fluorite deposits cannot be used in hydrofluoric acid production. Look also for Brazil to be a new source of fluorite in the near future. Consequently, prospects for the resumption of significant mining in the district in the foreseeable future are not bright.

As long as mines continued to operate in the Illinois-Kentucky fluorite district, mineral collectors had an ample supply of beautiful specimens for their collections. That source appears ended. In time, however, other interesting occurrences of minerals from this area may come to light.

LOCAL MUSEUMS

Two museums are or will be in operation in the Illinois-Kentucky fluorite district. The American Fluorite Museum (P.O. Box 755, Rosiclare, IL 62982/618-285-3513) is scheduled to open as this issue is going to press. Located in the administration office of the old Rosiclare Lead and Spar Company, this 2,200-square-foot facility will contain mineral specimens, mining equipment, the Ozark-Mahoning Company geology library, and historical materials relating to the miners of the district. Plans call for it to be open several days a week and by appointment. Fluorite-rich dump material may be deposited on the site for visitors to search through for specimens. Later the miners' changing room, engine room and one headframe will be refurbished. Other structures on the property will be dismantled for safety reasons, and the area will be converted to a nature preserve.

The Ben E. Clement Museum, located in Marion, Kentucky, is open Saturdays from 10 a.m. to 2 p.m. and by appointment. Admission is $3. The family of the late Ben E. Clement, a Kentucky fluorite mine operator, donated his personal collection of 10,000 to 15,000 mineral specimens (2,000 of which are on display). Exhibits include fluorescent Franklin, New Jersey minerals, of which Mr. Clement had about 2,000 specimens, and of course many Illinois-Kentucky specimens. Other holdings include 600 historical photographs, 3,000 mine maps and diagrams, and numerous pieces of mining and blacksmithing equipment. The museum currently occupies about 3,300 square feet but has room to expand to three times that size in the future. For more information call the County Judge (502-965-5251) or the Crittenden County Chamber of Commerce (502-965-5015), or write to the Ben E. Clement Mineral Museum, P.O. Box 391, Marion, KY 42064.

FIELD TRIPS

This article is the result of continuous field work in the district since 1982. At least once each year, I lead a college group on a field trip into the district. Several field trip guides have been produced (cited in the bibliography). Any geology professor interested in bringing students into the district may contact the writer on departmental stationery and I will assist in either organizing or leading a trip.

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The author is interested in receiving further information about district occurrences not mentioned here.

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Symposium on Copper and Copper Minerals

18th ANNUAL MINERALOGICAL SYMPOSIUM

10:15 A.M. to 1:15 P.M.
Saturday, February 15, 1997
PROGRAM

10:15–10:25 am	Introductory remarks—Symposium Chairperson ***Dr. Karen J. Wenrich***
10:25–10:50 am	The chemistry of the secondary copper phosphates and silicates ***Dr. James L. Sharpe*** and ***Dr. Peter A. Williams****
10:50–11:15 am	The mineralogy of the Caledonia mine, Ontonagon County, Michigan ***Tom Rosemeyer***
11:15–11:40 am	Chalcocite from the Flambeau mine, Ladysmith, Wisconsin ***Casey L. Jones*** and ***Dr. Gene L. LaBerge***
11:40 am–12:05 pm	Occurrence of turquoise group minerals in the eastern United States ***Dr. Henry Barwood***
12:05–12:30 pm	New Mexico copper minerals ***Ramon S. DeMark*** and ***Paul F. Hlava***
12:30–12:55 pm	Copper minerals in the Grand Canyon, Arizona ***Dr. Karen J. Weinrich* and*** ***Wayne C. Leicht****
12:55–1:20 pm	The supergene copper minerals of Bisbee, Arizona ***Richard W. Graeme***
1:20–1:45 pm	Philolithite, a new mineral from Långban named in honor of the Friends of Mineralogy ***Dr. Anthony R. Kampf,* Dr. Paul B. Moore, Dr. Eric Jonsson, Dr. P. K. Sen Gupta, and Dr. George H. Swihart***

* Speaker

INTRODUCTION

The 18th annual Tucson Mineralogical Symposium, sponsored by the Friends of Mineralogy, the Tucson Gem and Mineral Society, and the Mineralogical Society of America, is to be held in conjunction with the 43rd Tucson Gem and Mineral Show on Saturday, February 15, 1997. Copper and Copper Minerals are the featured minerals at the 1997 Tucson Show, and are the subject of the 1997 mineral symposium.

The word copper comes from the Greek *kyprios*, for the island of Cyprus, where some of the earliest mining of copper occurred. There are over 440 copper minerals reported in the *Glossary of Mineral Species*. The majority of these, particularly the supergene copper minerals, occur in various shades of green or blue. The brilliant blues and green of azurite and malachite and the red of cuprite commonly give them prominence in many minerals collections. Although a green color usually results when copper forms minerals with uranium, some minerals, such as cuprosklodowskite, tend to a yellowish green. With the exception of chalcopyrite, bornite and covellite, the primary and secondary copper sulfides tend to be dull and fine-grained, in shades of black, brown and gray.

Copper ores are found throughout the world, but in the United States when copper is mentioned two areas usually come to mind: Arizona and the Keweenaw Peninsula, northern Michigan. Although Michigan is prominent for its massive native copper, Arizona is equally famous for its high-grade vein deposits, such as Bisbee, and its huge open pit mines of low-grade porphyry copper that have yielded over 54% of the total U.S. copper production. Although spectacular mineral specimens are not, as a rule, found in low-grade sulfide deposits, colorful and exotic minerals have come in gratifying abundance from the oxidized portions of many of these deposits, such as Morenci and New Cornelia (Ajo).

The papers for this symposium discuss various copper deposits across the United States and in Australia.

K. Wenrich

The Chemistry of the Secondary Copper Phosphates and Silicates

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Intense weathering of copper deposits causes, *inter alia*, the mobilization of silica and phosphate due to the breakdown of silicate minerals and apatite. As a result, characteristic suites of secondary copper minerals are developed. Secondary copper phosphates commonly form in such circumstances, frequently associated with chrysocolla. These are often overlooked in oxidized ores, although pseudomalachite, $Cu_5(PO_4)_2(OH)_4$, is a *common* mineral in Australian oxidized zones. The chemistry of formation of chrysocolla, $\sim CuH_2SiO_4 \cdot H_2O$, pseudomalachite, libethenite, Cu_2PO_4OH, and cornetite, $Cu_3PO_4(OH)_3$, has been described (Williams, 1990, 1996) and can be related to general weathering processes and reported mineral assemblages.

Solution pH represents an important control on mineral stability with libethenite being formed at low pH relative to pseudomalachite and cornetite at high pH, for constant Cu^{2+}(aq) activity. Thus the presence of carbonates in gangue or host rocks can lead to the crystallization of cornetite, such as in the Great Australia mine, Cloncurry. However, available hydrogen phosphate ion activities superimpose a second control on the paragenesis and extent of secondary copper phosphate mineralization. When weathering is most intense, near-surface, elevated phosphate activities lead to the preferential formation of libethenite. This effect can be observed in the oxidized zones of a number of deposits in the Mt. Isa Inlier, Australia, and in the southwestern United States. In line with these observations, when strong leaching accompanies weathering, and phosphate is transported down the profile, libethenite crystallizes first, in general, followed by pseudomalachite. The latter species persists to considerable depths in several deposits, notably at Girilambone, New South Wales.

Chrysocolla cannot directly replace the secondary phosphates, azurite, $Cu_3(CO_3)_2(OH)_2$, or malachite, $Cu_2CO_3(OH)_2$, except under chemically extreme conditions (for the latter case). Thus mixed secondary copper phosphate and chrysocolla assemblages are quite common near the surface in many deposits from the above-mentioned areas. Chrysocolla endomorphs after libethenite are described, as well as the probable mechanism of formation of chrysocolla pseudomorphs after azurite.

WILLIAMS, P. A. (1990) *Oxide Zone Geochemistry*. Ellis Horwood, Chichester.

WILLIAMS, P. S. (ed.) (1996) *Notable Australian Mineral Deposits. Proceedings of the Joint Mineralogical Societies Conference*, Sydney.

Mineralogy of the Caledonia Mine Ontonagon County, Michigan

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The Caledonia mine, located near Mass City, Ontonagon County, is situated at the southwest end of the famous Michigan native copper province. The mine was first worked in 1863 and continued intermittently until 1881, with a production of 1.4 million pounds of copper. The mine lay dormant until 1937 when Calumet & Hecla conducted diamond drilling and drove the 4 level adit drift, but further work was curtailed by World War II. From 1950 to 1958 Calumet & Hecla again operated the mine and produced 5.5 million pounds of copper. Total production for the mine was 6.8 million pounds of copper, produced from the mineralized flow tops of the Evergreen Series.

In the mine area, the Evergreen Series consists of at least six basaltic lava flows with a maximum thickness of 630 feet that strike N 35° E and dip approximately 45° to the northwest. The Knowlton flow, which is about 45 feet thick, is the uppermost flow in the series. The fragmental amygdaloid (brecciated flow top) of the Knowlton lode is about 8 feet thick and is the mineralized portion of the flow that has accounted for most of the production from the Caledonia mine.

The mineralogy of the Caledonia mine is typical of the area mines and consists of quartz, calcite, epidote and red K-feldspar that fill amygdules and cement rock fragments. Native copper and silver are the economic minerals present. Datolite and adularia occur as open-space fillings and in late-stage veins.

In 1985 Red Metal Minerals acquired the mineral rights for the Caledonia and surrounding mines. Later, the 4 level adit was reopened and rehabilitated. For the past 11 years specimen mining has produced many fine specimens from the Caledonia mine.

A steeply dipping "feeder" fissure vein was discovered in the 850 stope, 4 level, in 1994, and subsequent mining of the fissure produced an array of specimens not seen since the heyday of the "copper country" when dozens of mines were operating up and down the range.

Exceptionally well-crystallized arborescent silver crystal groups several centimeters in size were encountered in a calcite-filled pocket and proved to be some of the finest silver specimens mined in decades. Another zone produced copper in scalenohedral calcite crystals up to 4 cm long, in groups and as singles perched on spongy native copper. Another pocket produced 1-mm silver cubes oriented on crystallized copper. Further mining of the fissure should produce specimens for years to come.

Chalcocite from the Flambeau mine, Ladysmith, Wisconsin

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Chalcocite crystals produced by supergene enrichment of a Cu-Zn-Au massive sulfide deposit in the Flambeau mine rank among the best in the world. Crystal-bearing pockets several cubic meters in size occur along the length of the orebody, but the largest pockets are at the western end.

The outer margin of the pockets consists of "ropy" or cellular chalcocite with little crystal development. Inward from the cellular margin are skeletal chalcocite crystals, or crystals with curved or rounded faces, which are overgrown by partial crystals with moderately well-developed faces. Some pockets contain spectacular euhedral crystals to 8.0 cm across in a wide variety of crystal habits. Individual crystals occur, but clusters of parallel growth crystals are more common. Cyclic twins forming pseudohexagonal plates are relatively common, and rarely, (110) penetration twins producing elongated crystals to 6.3 cm that are x-shaped in cross section.

The blue, purple, bronze, gold and iridescent patinas so distinctive of Flambeau mine chalcocites results from a thin coating of bornite. The gray color, typical of chalcocite from most localities, is uncommon.

The chalcocite crystals formed late in the enrichment process, because they developed within the massive granular chalcocite that constitutes a majority of the ore. The chalcocite formed just below the water table during deep (at least 80 meters) chemical weathering in Late Precambrian time, when North America was in a tropical environment and Wisconsin was near the equator. When movement of crustal plates carried North America into more temperate climates the water table rose to near the surface. As the water table rose, the chalcocite crystals were covered with deeper levels of groundwater, in which bornite is the stable copper mineral, and a thin coating of bornite was deposited on the earlier chalcocite crystals.

Occurrence of Turquoise Group Minerals in the Eastern United States

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Most collectors associate turquoise group minerals with the Western United States, where large and rich deposits of gem-grade material have been mined for centuries. Mineral collectors are generally aware of the turquoise crystal locality near Lynch Station, Virginia, but seldom know about other eastern U.S. sites where turquoise, planerite and coeruleolactite have been found. Turquoise group minerals have been found abundantly in Pennsylvania, Virginia, Georgia, Alabama and Arkansas.

In Arkansas turquoise and planerite are found in the Arkansas Novaculite (with iron phosphates) and in the Bigfork Chert (with aluminum phosphates). Massive turquoise was mined from novaculite at Porter Ridge (also known as the Mona Lisa or McBride mine) in Polk County during the 1980's. Production figures are not available, but "many tons" of both hard and chalky turquoise were produced. The turquoise was processed and sold for lapidary use. Thin veins of planerite are common on Buckeye Mountain in Polk County and other iron phosphate localities as well as the type section of the Novaculite at Caddo Gap. At the Coon Creek mine in Polk County, rare, tiny green crystals of a mineral, originally identified as "rashleighite," but now believed to be more like planerite, are found. Planerite occurs with wavellite and variscite in the Bigfork Chert at Mauldin Mountain, near Mt. Ida in Montgomery County. Most of the other wavellite and variscite localities in the Bigfork Chert also produce small amounts of planerite or turquoise.

Alabama and Georgia have a number of planerite occurrences, but two are exceptional. At Erin in Clay County, Alabama, black carbonaceous shales are cut by quartz veins that contain wavellite and planerite in some abundance. The planerite here is generally greenish and just approaches having distinct crystals. At the Brewer mine east of Cedartown, Georgia, similar veins of green and blue-green planerite occur along with wavellite, crandallite, aluminum-strengite and cacoxenite. Rarely, the planerite from the Brewer mine forms distinct green crystals and appears very similar to the material from the Coon Creek mine in Arkansas.

Virginia is well-known for the turquoise crystals from the Bishop mine near Lynch Station. This long abandoned (and many times re-worked) manganese mine has produced magnificent deep sky blue turquoise crystals. The mine is in the Mount Athos Formation, and was originally developed by a now collapsed shaft. Crystals coat a graphitic schist and quartz veins, with the best crystals on the quartz. Little is known about the exact paragenesis of the turquoise at this locality. Turquoise (planerite?) was found in residuum from the Shady Dolomite as vesicular masses coated with wavellite crystals at the Kelly Bank mine near Vesuvius, Virginia. Specimens could be found in some abundance on the old dumps. Unfortunately, Forest Service reclamation has obliterated this once productive mineral locality.

In Pennsylvania, turquoise (planerite?) has been found in residual clays west of Mt. Holly Springs in Cumberland County. The mineral occurs here with iron and aluminum phosphates in a clay residuum of the Tomstown dolomite. The turquoise is massive and light blue. The only U.S. occurrence of the mineral coeruleolactite, a member of the turquoise group, was General Timble's mine near East Whiteland in Chester County, Pennsylvania. General Trimble's mine was worked in the early 1800's and it is not known if any trace of it still exists. Green crystals of "turquoise" were also reported from the Bachman mine near Hellertown, Northampton County, Pennsylvania, but never confirmed.

The turquoise group, as redefined by Foord and Taggert (1986), presents some analytical problems for the eastern U.S. specimens examined so far. X-ray diffraction and microprobe examination of specimens from many of these localities has revealed complex variations in both diffraction patterns and composition. The earliest formed planerites tend to be fibrous and low in iron, while later formed, and typically more crystalline material, has a higher iron content. Copper content in the planerites seems to parallel the iron content with higher copper content being associated with higher iron content. The general formula for the turquoise group is $AB_6(PO_4)_4(OH)_8 \cdot 4H_2O$, where A= vacant site, Cu, Fe, Ca or Zn and B= Al, Fe, Cr. Most specimens examined during this study have "A" positions occupied by combinations of vacant sites, copper and ferrous (?) iron and "B" positions occupied by variable aluminum and ferric (?) iron.

Turquoise group minerals in the eastern U.S. are often associated with residual iron or manganese deposits with no obvious source of copper (with the exception of those in the Arkansas Novaculite, where native copper is found in some units of the formation). The ability of manganese and iron oxides to selectively absorb metals such as copper, silver, nickel and cobalt is well documented and contents of these metals up to several percent have been reported. The possibility that turquoise and planerite in many of the Eastern U.S. occurrences derive their copper content from associated iron/manganese oxides, and not from distinct copper mineralization, cannot be discounted.

Documentation of the analytical results of this study will be presented along with a description of many of the localities and the minerals found there.

New Mexico Copper Minerals

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Copper minerals are widespread, numerous, and abundant in New Mexico. Eighty-one species have been reported from throughout the state (Northrop, 1996). All but six of New Mexico's 33 counties have copper mineral locations. Socorro County heads up this list with 47 species, followed closely by Grant County with 43 species. Five additional counties report over 20 species each and eight more counties have a minimum of ten species.

Copper sulfides predominate with 16 species while sulfate (12 species), arsenates (10 species), and phosphates (9 species) contribute significantly, so that these four chemical groups represent more than half of the New Mexico copper minerals. Elemental copper has been reported from 18 counties from north to south although it is most prominent in the southwest part of New Mexico, particularly in Grant County.

Turquoise must be considered as one of the most significant New Mexico copper minerals because it is a well known, attractive and highly regarded gem material mined for millennia by Native Americans for religious reasons, personal, adornment and trade. Even today, Pueblo, Navajo and Zuñi artisans are admired for their work incorporating this beautiful copper phosphate. Excellent examples of their art can be seen on any day in the plazas of Santa Fe and Albuquerque's Old Town. Important turquoise locations are found from the north near Cerrillos in Santa Fe County to the southwest "boot heel" near Hatchita, Hidalgo County.

Economically more important is the copper production from the huge open pit mine operated by Phelps-Dodge Corporation near Silver City in Grant County. Large reserves of copper sulfide-bearing low-grade porphyry ore are expected to keep New Mexico a major copper producer for the foreseeable future.

For those interested in copper minerals as specimens, world-class linarite crystals were found in the Sunshine #1 tunnel of the Blanchard mine near Bingham, New Mexico in 1980. Unique and distinctive are most appropriate terms for the drusy linarite pseudomorphs after galena and malachite pseudomorphs after linarite that also occur at the Blanchard mine. Colorful specimens of grass-green brochantite, often associated with the very rare spangolite from the Blanchard mine and nearby Mex-Tex mine, are highly sought after by mineral collectors from around the world.

In 1981, Brian Huntsman made a significant contribution to the inventory of New Mexican copper mineral specimens when he found beautiful clusters and single crystals of azurite from the Hanover #2 mine in Grant County. Large numbers of perfect, lustrous crystals were recovered from a fault gouge in the abandoned mine.

Another unique copper mineral assemblage with the New Mexico stamp of recognition is the native copper and cuprite replacements after azurite from the Rose mine in Grant County. Individuals crystals and "roses" are easily identifiable as New Mexico specimens.

Chalcopyrite has been found in noteworthy specimens in several New Mexico locations. For sheer size however, the crystals from the San Pedro mine in Santa Fe County stand alone. Single disphenoids over 9 cm on an edge have been found there. The crystals are generally altered to malachite on their surfaces and the grouping of these magnificent chalcopyrite crystals with similarly-sized, scalenohedral calcite crystals provides for the easy recognition of specimens from this location. The prize for the most attractive chalcopyrite specimens from New Mexico must go to those from the Ground Hog mine near Vanadium, New Mexico. Brilliant crystals perched on slender quartz crystals, often associated with lustrous sphalerite crystals certainly make for handsome and desirable specimens.

The prize for mineralogical (and/or paleontological) interest goes to the occurrences of fossil wood replaced by chalcocite at several New Mexico locations. Most prominent is the Nacimiento mine near Cuba in Sandoval County, where entire logs were replaced by chalcocite and were actually mined as part of the ore! In the Scholle district of Torrance County, Steve Bringe and Marc Wilson reported that the fossil wood is replaced by djurleite. This is the only New Mexico location where this is known to occur.

For those interested in rare and elusive copper species, microminerals from agardite-(La) to volborthite are found throughout many of the now inactive mining districts of New Mexico. For example, rajite was first described by Williams (1979) as a natural cupric pyrotellurite from the Lone Pine mine in Catron County. Surely there are other species out there just waiting to be discovered!

NORTHROP, S. A. (1996) *Minerals of New Mexico*. Third edition, rev. by F. A. LaBruzza, Albuquerque, NM, Univ. of New Mexico Press.

WILLIAMS, S. A. (1979) Rajite, naturally occurring cupric pyrotellurite, a new record. *Mineralogical Magazine*, 43:91–92.

Copper Minerals in the Grand Canyon, Arizona

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The Grand Canyon is famous for its cliffs, canyons and brightly colored rock layers. Yet, ask mineral collectors and the words that come to mind when the Grand Canyon is mentioned are cyanotrichite and the Grandview mine. Mining is no stranger to the Grand Canyon; it began in the 1870's. At that time, production was primarily for copper and minor amounts of silver, lead and zinc. It was not until the late 1940's that uranium was first recognized in the Grand Canyon. The finely tuned eyes of prospectors roaming the canyons in search of wealth missed few surface exposures of malachite or azurite within the cliffs and tributaries of the Colorado River. Old copper mines include the Apex (slightly to the northwest of the Grand Canyon proper), Chapel, Copper House, Copper Mountain, Cunningham, Grand Gulch, Grandview, Hack, Orphan, Ridenour, Savannic, and Snyder mines. The copper in all of these mines was deposited as part of a mineralizing stage that occurred in the Grand Canyon between 260 and 200 million years ago within solution-collapse breccia pipes. A breccia pipe is a vertical pipe-like column of large, angular, broken fragments that are cemented together in a finer-grained matrix. Because of the coarse-grained and initially porous nature of these breccia pipes, along with a reducing environment, mineralizing fluids that passed through some pipes deposited a large suite of metallic minerals.

The primary metallic minerals include a large suite of copper, uranium, lead, zinc, silver, nickel, cobalt, arsenic, iron, and molybdenum sulfides. Many of them occur only in microscopic sizes (siegenite, rammelsbergite, linnaeite, lautite, tennantite) and most are uncolorful (galena, sphalerite, molybdenite, millerite, chalcocite), unlike the secondary minerals such as malachite, azurite and cyanotrichite. The erosion and dissection of the Grand Canyon during the past 5 million years is responsible for creation of the colorful secondary minerals through oxidation of the primary sulfides.

The Grandview mine, located below the South Rim on Horseshoe Mesa, is perhaps the most thoroughly studied for its copper minerals of the Grand Canyon mines, but appears to be representative of all the other old copper mines. Ore from the Grandview mine in the late 1880's was brought up the trail by mules and burros—each mule carried a load of about 200 pounds and could average a trip and a half per day down and up the 2,500 feet of vertical relief. The Grandview ore was of high quality—one piece of ore was reported to have contained 70% copper and weighed over 700 pounds. It was placed on exhibit at the World's Fair in Chicago in 1893.

The ore at the Grandview occurs in brecciated Supai Group sandstones and limestones that have been downdropped into dissolution cavities in the Redwall Limestone, forming a brecciated pipe of rock. The primary sulfides were probably present in the Grandview breccia pipe at, and for about 2,000 feet above the Redwall Limestone horizon, but have since been eroded off or severely oxidized to the present secondary minerals.

Copper minerals found in the Grand Canyon breccia pipes fall into six anion groups: sulfates, carbonates, arsenates, sulfides, oxides, and silicates. These minerals can be divided into primary and secondary occurrences—the primary minerals are sparse in the old copper mines, such as the Grandview:

Primary Copper Minerals		***Secondary Copper Minerals***	
Bornite	Tenorite	Antlerite	Devilline
Chalcopyrite	Tetrahedrite	Aurichalcite	Langite
Chalcocite		Azurite	Malachite
Covellite		Brochantite	Metatorbernite
Cuprite		Calciovolborthite	Metazeunerite
Digenite		Chalcanthite	Olivenite
Djurleite		Chalcoalumite	Parnauite
Enargite		Chrysocolla	Vesignieite
Lautite		Conichalcite	Volborthite
Tennantite		Cyanotrichite	Zeunerite

The Supergene Copper Minerals of Bisbee, Arizona

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Golden Queen Mining Co., Inc.
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The enduring fame of Bisbee lies totally with the strikingly beautiful supergene copper minerals that flowed from the many rich mines in amazing numbers for most of a century. From their beginnings in the late 1870's until closure in 1975, the mines of Bisbee, Arizona provided both the scientific and collecting communities with a wealth of material.

Just over 300 distinct species have been recognized from this deposit, including eight for which the district is the type locality. Among the recognized species, some 59 that contain copper are known to occur as a result of supergene processes. The finest known examples of a number of supergene copper minerals were found at Bisbee: antlerite, bisbeeite, brochantite, chalcoalumite, claringbullite, conichalcite, crednerite, cuprite, delafossite, graemite, nantokite, paramelaconite, paratacamite, rosasite and spangolite.

Also, it can easily be argued that Bisbee may well have been the source of the best examples of these supergene copper minerals as well: aurichalcite, connellite, cyanotrichite, malachite and shattuckite.

To be certain, it is the spectacular specimens of azurite and malachite that are most associated with the name Bisbee, and justifiably so. Many thousands of these specimens grace collections everywhere. The uncommonly wide variety of habits and hues that can be found in the azurites and malachites from this locality is unequaled anywhere. This variety is largely a result of multiple episodes of supergene activity, often with moderately different chemical and/or physical characteristics. In many instances the same area was subjected to several periods of such activity, each leaving a distinctive habit and/or hue of one or both of these copper carbonates.

Philolithite, a new mineral from Långban named in honor of the Friends of Mineralogy

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Philolithite, $Pb_{12}O_6Mn(Mg,Mn)_2(Mn,Mg)_4(SO_4)(CO_3)_4Cl_4(OH)_{12}$, is a new mineral from the Långban mines, Filipstad district, Värmland, Sweden. The name is from the Greek *philos* (= loving) and *lithos* (= stone) in honor of the Friends of Mineralogy. The mineral occurs as massive granular aggregates and simple tetragonal tablets in small cracks in Mn-rich skarn consisting principally of fine-grained hausmannite, biotite (manganophyllite), and calcite. Other associates are native lead, native copper, and hydrocerussite. Philolithite is inferred to be a low-temperature product of hydrothermal reworking of the skarn by basic brine.

Philolithite has no cleavage. Its fracture is conchoidal, streak is white, luster is vitreous to adamantine, Mohs hardness is 3–4, and calculated density based on the structural formula is 5.91 g/cm^3. Crystals exhibit anomalous biaxial (+) optics ($2V \approx 60°$) and sector twinning about the *c*-axis. Indices of refraction are greater than 1.92, but could not be measured because crystals decompose immediately in higher-index liquids. Observed crystal forms are {001} and {111}. Philolithite is tetragonal, space group $P4_2/nnm$, a = 12.627(9), c = 12.595(9) Å, V = 2008(2) Å^3, Z = 2. EDS analysis provided PbO 73.7, MnO 10.3, MgO 1.8, SO_3 1.7, Cl 3.4, CO_2 4.9, H_2O 3.0, O = Cl -0.8. TOTAL 98.0. H_2O and CO_2 deducted from the structure analysis. The seven strongest powder diffraction lines are [d(Å)(I)(hkl)] 2.975 (100) (330, 303), 3.99 (30) (301), 2.752 (30) (421, 412), 8.95 (20) (110), 7.30 (20) (111), 2.473 (20) (413), 1.716 (20) (633, 336).

The atomic structure, refined to R = 0.053 for 814 $F_o > 4\sigma(F_o)$, involves an elegant trellis-like framework consisting of edge-sharing MnO_6 octahedral chains linked by MnO_4 and SO_4 tetrahedra. Pb and Cl atoms occupy the open spaces between the trellis members, and CO_3 groups further link MnO_6 octahedra to Pb atoms. The structure can also be viewed as a cubic close packing of O, Cl, and Pb atoms.

What's New in Minerals

Denver Show 1996

by Thomas Moore

[September 8–15]

Well, this week's war with Iraq may be starting up soon, the presidential campaign moves forward inexorably, your favorite team is probably hopelessly out of the pennant race, and back on my own home turf in Connecticut there's some scare about an equine-encephalitis-bearing mosquito coming in from Rhode Island. But none of *that* matters; it's Denver Show time! And inside this little bipolar realm of Holiday Inn North/Denver Merchandise Mart (where the shuttle vans are always timely, and free), the world goes away. Of course, we'll all soon be getting back to it—real life. But the charm of living inside the hothouse of one of these great shows is that the friendly-good-fellowship dial in the invisible control room seems always to be set on High; exotic life flourishes; we thrive like misted ferns in the richly mineralized soil of our harmless, obsessive, benevolent common concern. Except for a glance at the morning's TV news with my coffee, I follow no wider affairs; and it serves them right, those droning affairs. Did I mention that Marty Zinn's Holiday Inn poolside auction went swimmingly? that topaz was the theme mineral of the Main Show? that Ralph Clark again displayed his incredible thumbnails? that gem tanzanite has been everywhere one seems to look?

To describe the tour along orderly, familiar lines, I'll circle much of the globe systematically while combining descriptions of offerings at the hotel and Main shows.

This final (?) year of Bryan Lees' extraordinary 6-year mining run at the Sweet Home mine, Alma, Colorado, has yielded another couple of great pockets, and thus a last **rhodochrosite** hurrah. At the end of June, in the Main Stope, the miners breached what came to be called the "Blue Moon Pocket," where very large, very bright rose-red rhodochrosite crystals sat isolated on beds of needle quartz with sulfides. The star "Blue Moon" specimen for sale in Denver seemed to reach out to visitors like a searchlight from where it sat in a case inside the Collector's Edge booth at the Main Show—such was the wonderfully vivid (and well backlit) clean roseate color of its lone crystal, a 12 x 12 cm compound rhombohedron centrally placed on a 15 x 30 cm matrix plate. This crystal has many steplike parallel growth features, much like the one on the famous old "Bancroft" piece, though in overall aspect the specimen is like a junior-edition Alma King, as the flat matrix is blanketed with needle quartz and patchy sulfide druses. If by any chance you could not afford to buy this one (or another one of the twelve or so super-top pieces that the pocket produced), many other Blue Moon specimens were on view here, including some nice examples of purple cubic **fluorite**, and two flats of thumbnails and toenails of the best **galena** crystal groups yet found in the Sweet Home mine—bright, sharp, cuboctahedrons to 1.5 cm, with sparkling sphalerite and tetrahedrite.

The second 1996 pocket, the "Hedgehog," has produced more fine rhodochrosite crystals (of smaller average size though more elevatedly, fetchingly perched on quartz needles), but few of these were available yet, as the pocket was hit in August and most of its materials have not yet been fully cleaned and prepared. Anyway, the *Collector's Edge* booth was even more than usually exciting, though quite as usually jammed with gawkers. A hundred or so fine new Blue Moon specimens across a spectrum of sizes mingled with some also-fine holdovers from the Corner Pocket of 1994, and from earlier pockets still.

Contrasting (still at *Collector's Edge*) with all this Sweet Home pink were also some blue-greens and smoky blacks from a new **microcline-and-smoky quartz** prospect which Bryan Lees is now working: the Two Point claim in Teller County, Colorado. The quartz crystals are very dark and of the classic, slightly tapered Colorado style, while the microcline ("amazonite") comes in very sharp, blocky shapes up to 8 cm long, commonly of an ideal rich green color. Work in this prospect yielded most of the best specimens in May and June of this year, as simultaneously the Blue Moon pocket was being entered in the Sweet Home mine, so Bryan was one busy fellow for a while there. May of next year will see some serious dynamiting at the Two Point claim, so we may hope for more excellent "amazonite"/smoky quartz combo pieces from this new locality.

Also at the Main Show, Steve Rice of *Colorado Nuggets* (P.O. Box 964, Evergreen, CO 80437-0964) had about a dozen very fine **wire gold** specimens from the old Wire Patch mine, Breckenridge, Summit County. Some of these came out of old collections, while others, Steve said, had been recently found through the magic of metal detectors. On earthy reddish brown limonite gossan matrixes, the gold makes intricate little wire nests of rich yellow color and medium luster. Three of these pieces are thumbnails and the rest miniatures, except for one 10 x 15-cm matrix piece with wiry gold coagulations all over its top ($10,000).

Another great western bonanza for which this year will be remembered is of **wulfenite** from the venerable and much venerated Red Cloud mine in the Trigo Mountains of LaPaz County, Arizona. In my Tucson report I mentioned Wayne Thompson's then-just-beginning work at the Red Cloud, and in Vol. 27, no. 5 of the *Mineralogical Record* Wendell Wilson reported fully on the project and its present success, so I will not dwell on "background" here. Suffice it to say that in Denver, Red Cloud wulfenite specimens of almost every conceivable size and quality were all over the place, special honors going to the hoards of specimens offered by Dave Bunk, Les Presmyk, and, of course, Wayne Thompson himself; collectors now have their best chance in decades to pick up a good (or even "great") specimen. Wayne's room was full of hundreds of flat, dark brown rocks all fairly aflame in orange, including a number of the topmost pieces which he has so far taken out. As Wayne had an advance copy of the *Mineralogical Record* issue with article-plus-photographs (the

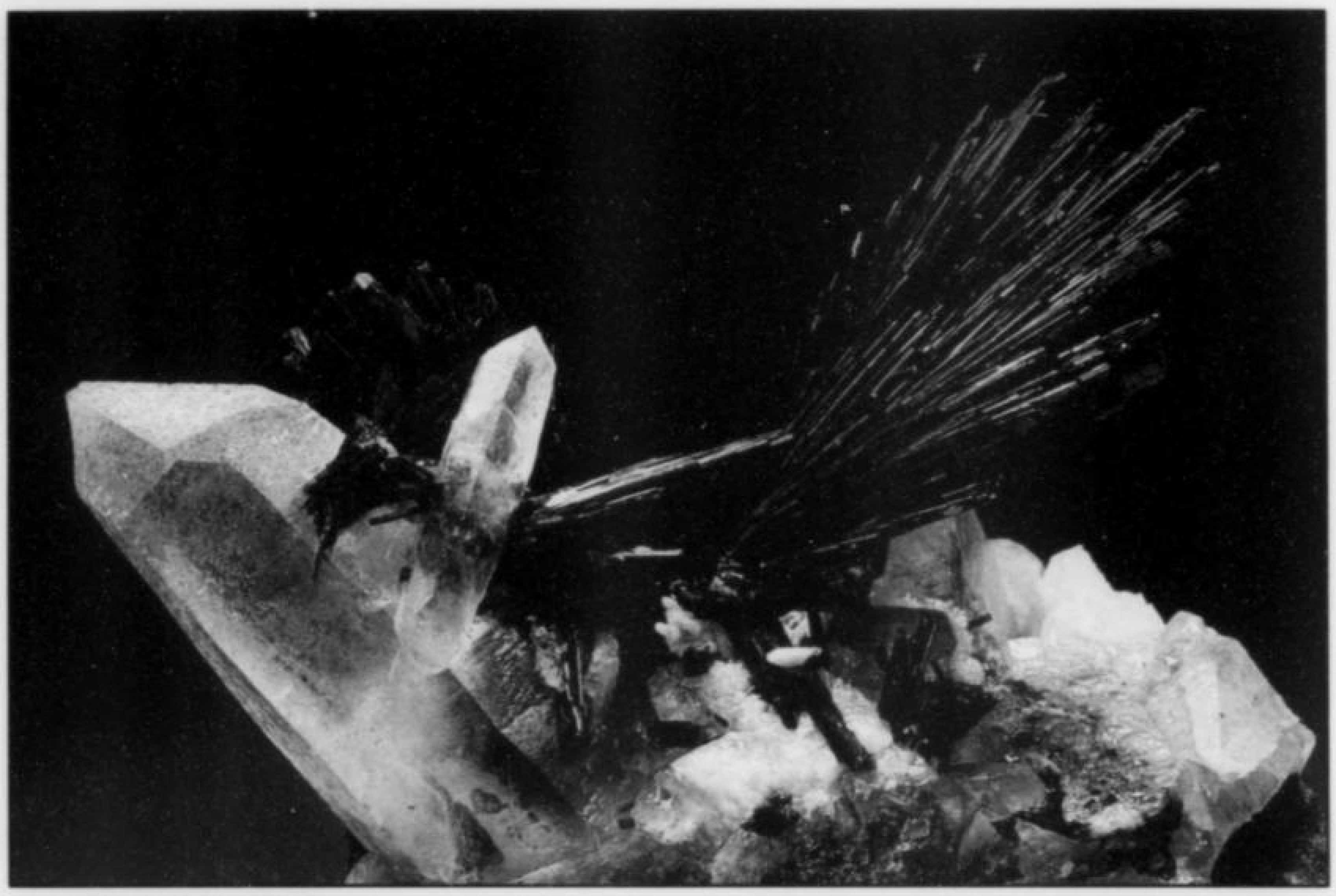
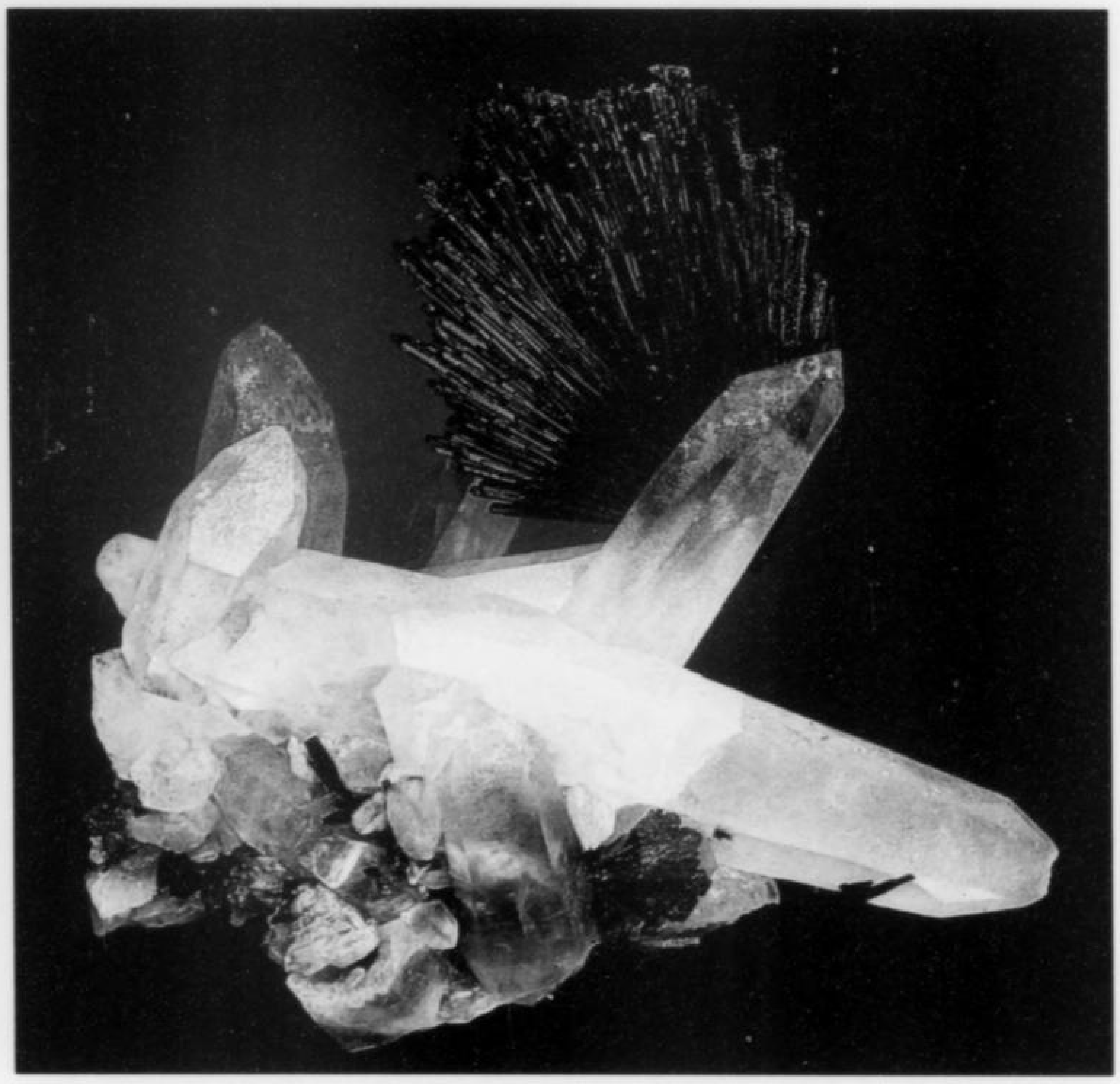


Figure 1. **Epidote and quartz crystal group, 7.6 cm across, from Ica, Ica province, Peru. Harvey Gordon Minerals specimen; Jeff Scovil photo.**

Figure 3. **Epidote and quartz crystal group, 11.4 cm across, from Ica, Ica province, Peru. Harvey Gordon Minerals specimen; Jeff Scovil photo.**

Figure 2. **Wulfenite crystals to 3 cm, from the La Aurora mine, Chihuahua, Mexico. Blue Sky Mining specimen; Jeff Scovil photo.**



Editor refers to it as the "Red Issue"), he could also play the match-photo-to-specimen game with collectors.

Carter Rich reports that at a small show in Maryland last June there appeared a small, recently collected lot of nice **datolite** from the Virginia Crushed Stone quarry in Loudon County, Virginia: maybe about 200 specimens, of which Carter had a small handful in Denver. The datolite crystals are transparent, lustrous, very pale green, and of tabular habit, to 2 cm across; the best matrix specimens hold up well in comparison with those from the northern New Jersey traprocks.

Another eastern U.S. surprise was the 20 lovely **celestine** specimens from a limestone quarry at Mandata, Cumberland County, Pennsylvania. According to Doug Wallace of *Mineral Search, Inc.* (11882 Greenville Ave., Suite 123, Dallas, TX 75243), these were dug from a series of pockets in August of this year. The medium smoky blue celestine crystals are highly lustrous and transparent with only some slight cloudiness, blocky to fat-prismatic, and reach 3 cm high; their matrix is a hard, buff-colored limestone with some drusy calcite as pocket linings. Specimen sizes range from small-miniature up to 30-cm blocks scooped out all over with deep vugs out of which rise the blue, shining celestine crystals. These, I'd say, rival all but the very best of the Sakoany, Madagascar, celestine geodes.

Although there seems to be little new from Canada this early

Figure 4. **Celestine crystal, 1.6 cm, on matrix from Cumberland County, Pennsylvania. Thomas Moore collection; Jeff Scovil photo.**

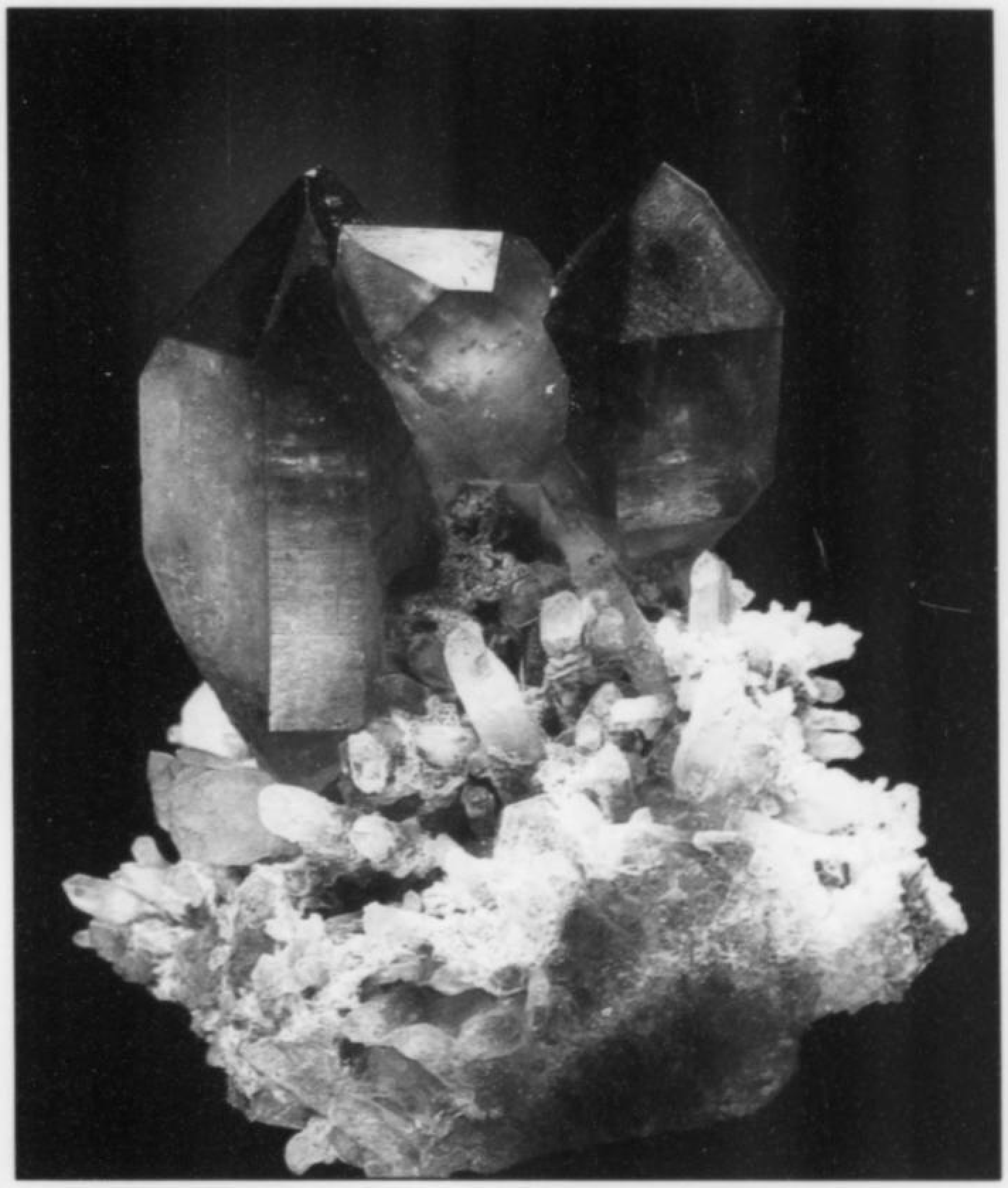


Figure 5. **Amethyst crystal group, 5.8 cm, from Tepustete, Alamos, Sonora, Mexico. Blue Sky Mining specimen; Jeff Scovil photo.**

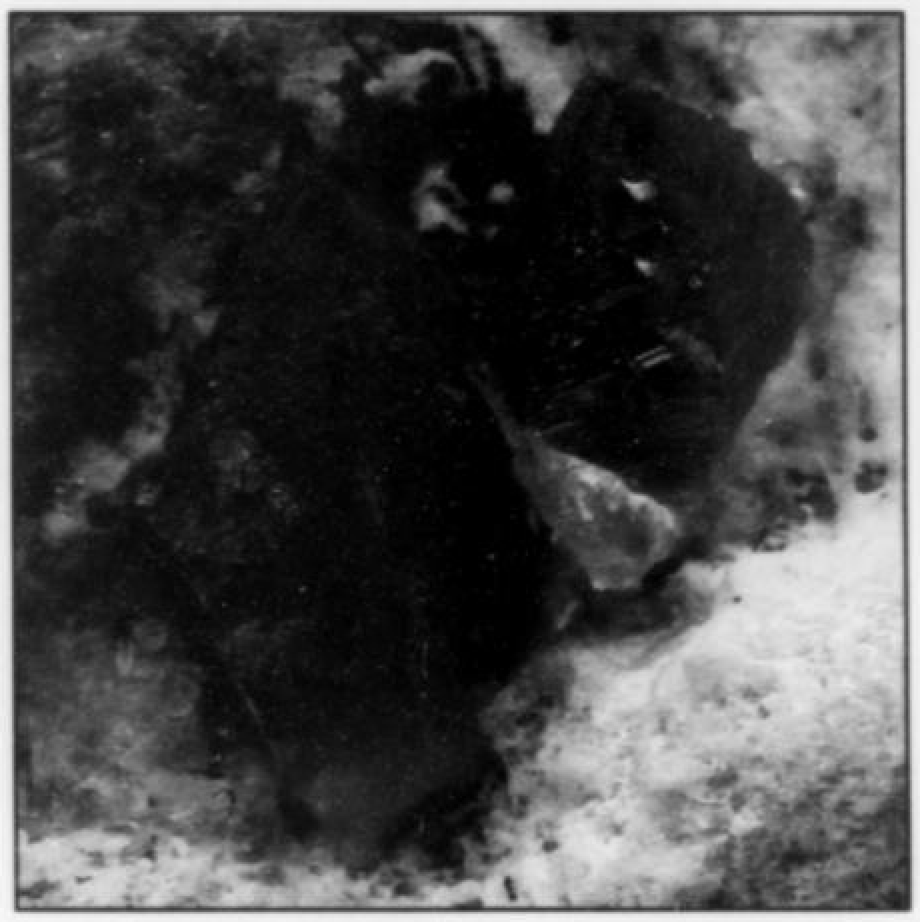


Figure 6. **Scheelite crystals to 1.5 cm from Santa Cruz, Sonora, Mexico. Blue Sky Mining Company specimen; Jeff Scovil photo.**

Figure 7. **Cubical gold crystal, 1 cm, on matrix from Beryosovsk, Yekaterinberg Oblast, Russia. John Barlow collection; Jeff Scovil photo.**

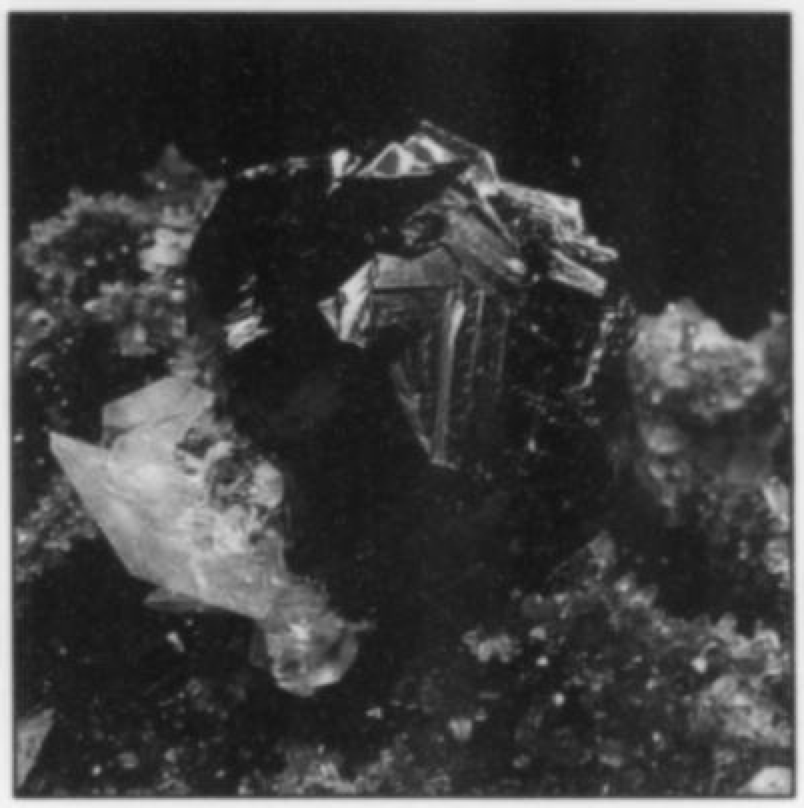


Figure 8. **Sphalerite crystal, 2 cm, on matrix from Taolin, Hunan, China. Dan Weinrich Minerals specimen; Jeff Scovil photo.**

autumn, Rod Tyson of *Tyson's Minerals* had about ten good **dolomite** specimens from the 1240 Bench of the now-closed Rabbit Lake mine on Wollaston Lake, Saskatchewan. These specimens were collected in the early 1980's. On three large cabinet specimens and some ten miniatures, dolomite occurs as sharp, simple rhombohedrons to 3 cm, of a peculiar opaque pinkish gray to pinkish brown color; the groups attractively cover the matrix, along with quartz crystals.

From Mexico, only a lone specimen makes the news this time, but *what* a specimen: a matrix-free pair of 5 x 5 x 10-cm prisms of **pyrargyrite** loosely attached at the bases, from the San Luis shaft, Fresnillo, Zacatecas. This must be among the biggest fine pyrargyrite specimens yet found at this locality—roughened on the terminations, and slightly slabby on some prism faces, but brilliantly lustrous, its two giant crystals, despite their thickness, alive with flashing red internal highlights. Dave Bunk was showing this piece in his room to all interested parties, but Dennis Beals brought it into the country, and a new owner has by now brought it home.

From Springfield a month ago I told you about having made my first, surprised acquaintance with the new **epidote** from Peru;

Harvey Gordon and a few other dealers had more, and more variously styled, specimens of this stuff at Denver, and moreover I can now give the locality more precisely: Pampa Blanca ("white plain"), Ica Province, Peru. Apparently, specimen mining is going on now in the skarn zone of the old iron mine there. While most specimens to be seen are still the loose sprays of prismatic crystals described from Springfield, there are also, sometimes, 6-cm fans of blackish green acicular epidote crystals rising from matrixes of large quartz crystals on an epidote/chlorite rock, with sporadic accompaniments of 1.5-cm white calcite scalenohedrons. Harvey had also about 30 miniatures, mostly of the loose sprays. Meanwhile, back at the Holiday Inn, Stefan Stolte of *Mineralien & Fossilien Galerie* (Fahrgasse 88, 60311 Frankfurt/Main, Germany) had some very beautiful, lustrous loose, sprays to 15 cm high. Back at Harvey's Main Show stand again, some excellent **andradite** garnet crystals were to be seen, in a few cabinet specimens from the same place, resting lightly, singly or intergrown, in vugs in the skarn breccia. The bright, simple, dodecahedrons can reach 2 cm across.

Bolivia has recently turned out some new supplies of "old" sulfosalt minerals, and also a new dealership: *Bolaños Minerals Company* (Edificio La Paz, Apt. 11, Oruro, Bolivia), which occupied a busy room in the Holiday Inn. The first thing the visitor saw here was a tableful of some 200 excellent thumbnail, miniature, and even small cabinet specimens of the long-familiar **copper pseudomorphs** after loose hexagonal prisms of aragonite, from Corocoro. The locality (as all along we've assumed) is long closed; this lot was collected, Marco Bolaños says, about 50 years ago, and will be the last to be seen. Specimens are either single floater hexagonal prisms, like elongated lug nuts, with slightly concave side faces, to 3 cm, or groups of two or three of these lightly attached. Some (unfortunately, if you ask me) have been bathed in sulfuric acid, so there is only the copper color, unnaturally bright, while the other, "natural" specimens show spotty coatings of a white clay, some green Cu-alteration staining, and a duller luster on copper surfaces; $30 to $50 could get you an excellent miniature group. And a couple of other dealers, most notably *Heliodor*, had a few more from what's clearly the same hoard.

Nor are the Bolivian offerings of Bolaños *finito* here. There were very plentiful thumbnails, sprinkled about the room, of most of the members of the sulfosalt suite found at the San Jose mine, Oruro, including **andorite**, **plumosite**, **franckeite**, **stannite** and **zinkenite**. Few of these were of top quality, but their profusion was striking. The zinkenite sometimes makes attractively bright specimens of loosely matted metallic gray prisms spotted with pyrite crystals; a couple of these were cabinet-size pieces attaining "major" status for zinkenite specimens. Finally, for a secondary-mineralization dessert, there were a few 3-cm pyrite matrixes with glassy, translucent, brownish white, 1-cm, terminated blades of **valentinite** lying flat, and there was one cute small thumbnail with a shining colorless spray of valentinite needles on sulfides (these valentinite pieces are also from the San Jose mine).

Now onward to sprawling, prolific-mineralific Brazil. In the Holiday Inn room of *Valadares Minerals*, Edson Endrigo was cheerfully (as usual) telling all comers about new digging activities at the "black quartz" vein occurrence at Fazenda Recruta, northwest of Vitoria da Conquista, Bahia (see the article in the November-December 1973 issue). The hydrothermal quartz/barite vein in a micaceous gneiss is marked by 1-meter pockets lined with large crystals of a truly *black* quartz (no translucency at all, even on thinnest edges of the lustrous bipyramids; no prism faces on these, either). Individual crystals reach 15 cm across, and specimens in every size from thumbnails to boulders have been taken out. The matrix appears to be a mottled yellow-brown mixture of chalcedony and barite. The new production began in April of this year and happily promises more, for these indeed are handsomely "different" items for quartz-suite assemblers.

Another remarkable revisitation in the Valadares room was of loose thumbnail-size single crystals and skinny parallel groups of **xenotime** from Ibitiara, Bahia—the self-same locality where occur also those hematite/rutile girderwork specimens so common in recent years. In fact, golden rutile blades can sometimes be made out clinging along the sides of the xenotime crystals. These latter are a rich dark brown color, translucent on some thin edges, their tetragonal-prism forms often topped by low pyramids. A good thumbnail run about $75.

And now for an overdue salute to the outstanding "Serro, Minas Gerais" specimens of very sharp, very bright black **magnetite** octahedrons in chlorite schist. These are much like the specimens from Chester, Vermont, except that the magnetite is much more highly lustrous, and some of the Brazilian crystals are spinel-twinned; some reach 1.5 cm on edge. Valadares had the best lot I have seen in a while: about 50 thumbnails and small miniatures.

The what's-new array from this show was remarkably Europe-poor, but the dumps of an old gold mine at Salsigne, Aude, France, did recently sweat out (perhaps in a kind of literal way, as a post-mining product) a new species, already approved by the IMA. It is **yvonite**, a copper arsenate, appearing as pretty, pale blue microcrystals on metallic matrixes of what is probably arsenopyrite, with green microcrystals of another rare species, the hydrated copper arsenate **geminite**. Small specimens of these exotica were to be had from Gilbert Gauthier at the Main Show.

Coming now to a major bedazzlement of this show, at which I've already hinted: suddenly there is a dramatic new flood of gorgeous "tanzanite" (zoisite) gem crystals from the Merelani mine, Arusha, Tanzania. I lost count of the dealers who had at least a few of these: Cal Graeber had a whole flat, including some 4-cm crystals, and Dudley Blauwet of *Mountain Minerals International* had many fine ones—just to name two. Werner Radl and Horst Bocksrocker of *Bora Gems Ltd.* (Ketterschwangerstr. 12, 87668 Rieden, Germany) displayed a flat caseful of everything from plastic bags of crystal sections, to fine individual gem crystals to 4 cm high, to a 5 x 5 x 10-cm *group* showing three long subparallel crystals (two of them broken off at the ends, however), to a *matrix* specimen 7 x 12 x 24-cm long with, in its middle, a V of lustrous, deep blue, gemmy tanzanite crystals, 2 x 3.5 cm and 2.5 x 2.5 cm. What *is* that matrix, you ask? Well, to judge from this piece and from one possessed by Beau Gordon of *Jendon Minerals*, it is a sparkling black **graphite** crystal druse heavily infused with tiny green **diopside** crystals; some of the loose tanzanite crystals around the show even showed modest drusy belts of medium-green diopside. Tony Kampf of the L.A. County Museum visited Merelani recently and reports that in some of the newer operations they are mining for the graphite, and take the tanzanite as a sweetener when it is encountered. As a general rule the tanzanite crystals are of fine gem quality. Some, perhaps most, have been heat-treated, in which case the characteristic red of the blue/purple/red trichroism is dampened. It appears that someone, not unmindful of the specimen market, has of late been very busy exporting these gems. Even more perhaps than Red Cloud wulfenite or Sweet Home rhodochrosite, this tanzanite manna was the talk of the show.

Sharing the hotel room with Bora Gems and its tanzanites were the ever-friendly Fabrice Danet and Denis Gravier of *Le Mineral Brut* (Hauterive, 01640 Saint-Jean-le-Vieux, France), longtime specialists in Madagascar minerals. What's new in this department is a little gathering of about 20 thumbnails and miniatures from a fine new **almandine** garnet occurrence somewhere in Madagascar (I'm promised specific locality data by Tucson-time, and I'd better get it, too, as I bought a thumbnail myself). The very sharp almandine dodecahedrons to 1.5 cm are a deep red, and they sit up well on a mottled white feldspar matrix, to make winning little specimens.

Rob ("Rocko") Rosenblatt's new dealership, *Rocko Minerals and Jewelry* (Southside Rd., Margaretville, NY 12455), was debuting in the big-show scene in a hotel room confidently well-stocked with interesting things chiefly from either upstate New York or from South Africa. The former material included some nice Walworth quarry colorless **fluorite**, Chubb Lake specular **hematite**, and sceptered **quartz** "Herkimer diamonds"; but more interestingly (to me anyway), Rocko was marketing some new N'Chwaning mine material for Clive Queit. About a month ago at the N'Chwaning mine a mineralized zone produced brilliant black, sparkling, upstanding pocket linings of **gaudefroyite** crystals, with spotty overgrowths of drusy bright red andradite. The terminated prisms of gaudefroyite can attain 1.5-cm, rising in jumbles from black massive hausmannite matrix, with occasional 5-mm white crystals which may be calcite, thaumasite, ettringite, or all of these. The best of the earlier gaudefroyite specimens to hit the market are loose, fat floater singles and floater clusters; but as a cavity-lining, prismatic species on matrix of all sizes the mineral looks even better. Then too from the N'Chwaning mine (*not* the Wessels), found in spring of this year, come some orange-pink encrustations of splintery millimetric **inesite** crystals over a gray brecciated shale. The crystals are not the vivid pink or red of those from the Wessels mine, but they are modestly pretty and come in all sizes.

The Van Scriver/Pliaskov dealership *Heliodor*, of Russian-minerals fame, had one new and one old/new item this time. First there is a rather astonishing specimen of **cubic gold** on a different kind of matrix and from a different locality than the smaller single specimen I mentioned seeing in Springfield. Here we have a dense, dark brown limonite matrix measuring about 4 x 4 cm, harboring a slightly rough, dull-lustered cube of gold fully 1 cm on edge. The locality is the Beriozovsk mine near the village of Beriozovsk outside of Yekaterinburg in the Middle Urals.

Then there were the two flats of beautiful **bornite** crystals from Mine 65, Dzhezkazgan, Kazakhstan; this is a new, large pocket in what is moreover a new mine at Dzhezkazgan, distinct from the operations whence fine bornite has previously come. These crystals are all extremely sharp, iridescent black trisoctahedrons; some are loose 2-cm singles, others are miniatures where the crystals sit on flattish plates covered with small quartz crystals. The most blockbustery of these bornite specimens has a 2.75-cm crystal shining with a kind of matte metallic purplish blue color, resting beautifully on a 3.5-cm quartz matrix ($3000). This new lot came out in March, and more lots of course may come later . . . but still, if you're into the world's finest bornite, you can and should get one now.

We conclude the survey in China. This giant country has been outdoing itself mineralogically during the past few months. Take first the gorgeous, brand new **sphalerite** from the Shizhuyuan mine, Chiangning, Hunan Province, that was in the keeping of Dan and Jill Weinrich (16216 Copperwood Lane, Grover, MO 63040). Highly complex, myriad-faced and busy, flashing with high adamantine luster, the rounded compound sphalerite crystals reach 3 cm. And, what's best, they have marvelous color and transparency: a gemmy red-brown tending to classic "ruby jack" red. They occur on glittering spongy matrix covered with drusy quartz and the odd 1-cm white calcite crystal. A few fine small cabinet specimens were on hand at the Weinrichs'; word is that more and even better are coming.

From a place called Xiang Hau Lin, Hunan Province, comes some fine **fluorite** in sharp, frosty octahedrons to 5 cm on edge, in groups on gray matrix. They are transparent below the frost, and either pale blue or a smoky gray-green in color, sometimes both on the same specimen. Groups of these which the Weinrichs (and others) had can reach 25 cm across.

Andreas Weerth was one of several dealers to have some very large groups (20 to 30 cm) of **calcite** from a new find at the Shanhauo Pu mine, Chenzhou Province. This is a fluorite mine, so that together with the 8-cm, translucent, smoky gray, flattened rhombs of calcite there can come solid plates or beltlike enfoldings of transparent, pale green **fluorite** cubes to 2 cm on edge. These are wonderful calcite/fluorite association pieces, with both minerals performing at their peak. *De Trin Minerals* specialized in groups of the icy green cubic fluorite; these lack associated minerals but can reach the size of a portable television.

Debbie Meng is proprietess of a fairly new enterprise, *Debbie Meng's Minerals* (P.O. Box 117, Marina, CA 93933), where she works with her daughter, who is as energetic, enthusiastic and English-fluent as Debbie herself. In this room at the Holiday Inn I found, in addition to more of the fluorites and many of the now-familiar matrix **emerald** specimens from Yunnan Province, at least three impressive new Chinese things. One is **chalcopyrite** from near the town of Yaogangxian, Hunan, in about 20 brilliant thumbnail groups reportedly collected 20 years ago by a Chinese geologist. They are a lustrous medium gold color; and the crystals are stacked and slightly skeletal (vaguely like those from French Creek, Pennsylvania, although much brighter). A few have bits of what looks like iridescent black hematite adhering. Next, from somewhere unspecified in Yunnan Province, there are some fine thumbnail-size single crystals and loose cyclic-twin groups of dark brown to resinous yellow **cassiterite**, these much resembling Panasqueira, Portugal, specimens. Finally, there was some lovely robin's-egg blue **hemimorphite** in thick mammillary pocket linings, glistening all over with tiny crystal faces. These came from a small, unnamed mine prospect. Ten cabinet specimens range up to 30 cm across. Debbie says that they are rare, but that she will soon go exploring actively, mostly on muleback, for more.

The Main Show this year bustled and hummed along as usual, with no changes in format, no diminution in the numbers of eagerly info-processing kids from the school tour groups, and certainly no decline in the quality of the exhibit cases. Prominent among those cases devoted exclusively to topaz, the theme species, were those of the Colorado School of Mines; the Royal Ontario Museum; the Denver Museum of Natural History (Colorado topaz); and the Cleveland Museum of Natural History ("historical" topaz specimens collected between 1890 and 1910 by Charles H. Jones of Metuchen, New Jersey).

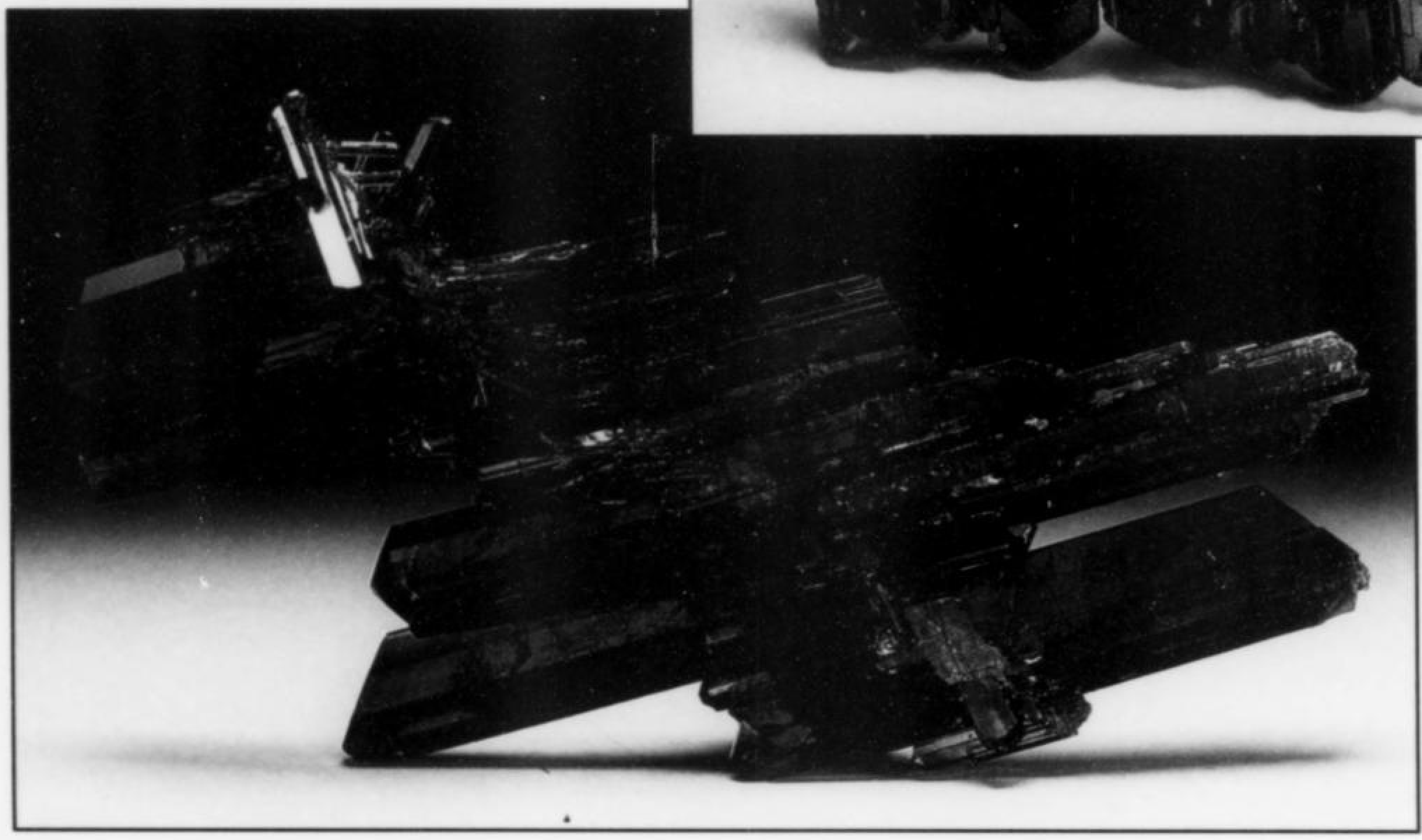
Then there were the spectacular mineralogical shows staged behind drool-spotted glass by the Smithsonian (smithsonite specimens); the Seaman Mineralogical Museum (amazing Keweenaw, Michigan, coppers); the American Museum of Natural History (a repeat performance of "Hidden Treasures," described in my last Tucson report); Bill and Carol Smith (twinning in minerals); Keith and Mauna Proctor (Indian zeolites); Mike Wheat (Mexican minerals); the Ouray County Museum (Colorado fluorites); Harvard (1972 Dunton mine, Maine, elbaite); and the Carnegie Museum (ten majestic Dalnegorsk, Russia, pyrrhotite specimens).

A case deserving of special notice was that of Yale University's Peabody Museum, arranged by collection manager Ellen Faller. Here, devotees either of ancient collections or of pseudomorphs, or of both, could admire about 30 specimens just lately dusted off and re-studied from the pseudomorph collection of Professor J. Reinhard Blum (1802–1883) of Heidelberg—donated to Yale in 1870, when G. J. Brush was curator. The complete collection has about 1,700 specimens, all cataloged, with complete descriptions of localities,

Figure 9. Epidote and quartz crystal group, 8 cm across, from Rosario Mabel, Mapa Blanca, Castro Virreyna, Huancavelica, Peru. François Lietard specimen; L. D. Bayle photo.

Figure 10. Epidote and byssolite crystal group, 4 cm across, from Ashudi, Pakistan. François Lietard specimen; L. D. Bayle photo.

Figure 11. Epidote crystals in a parallel grouping, 6.2 cm across, from Ashudi, Pakistan. François Lietard specimen; L. D. Bayle photo.



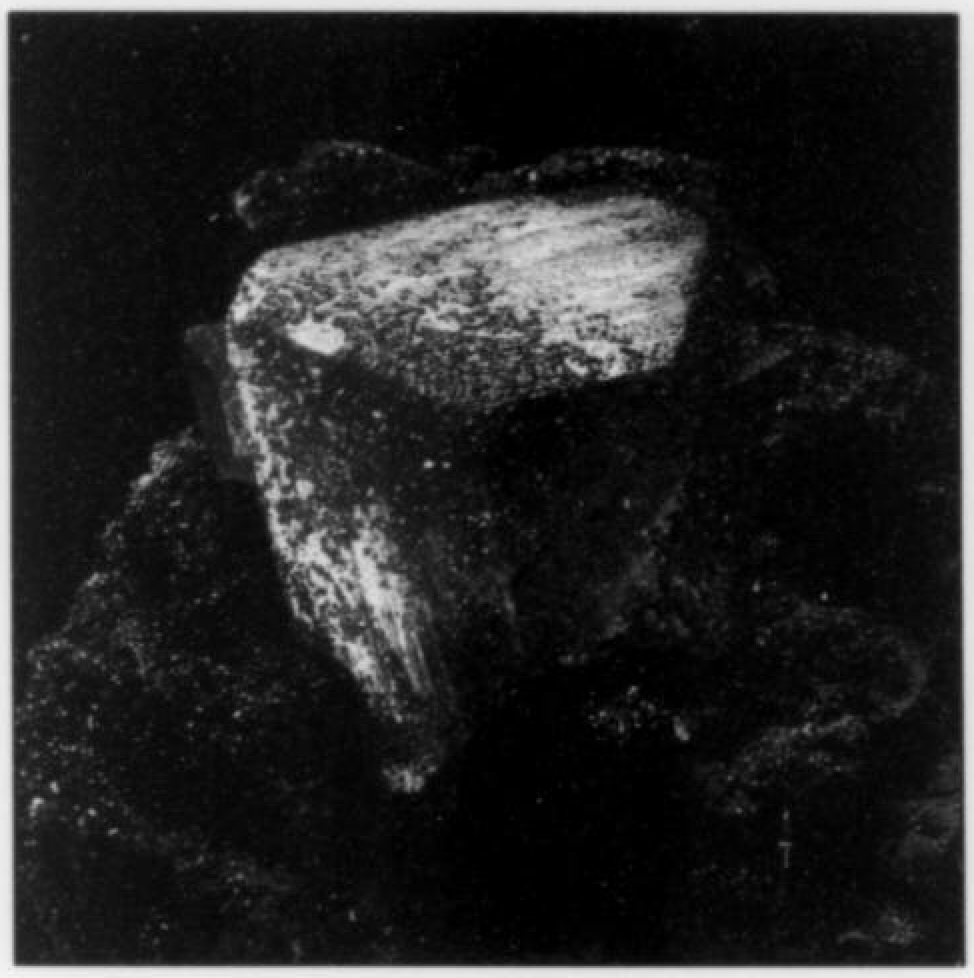


Figure 12. **Wulfenite crystal, 2.8 cm, on matrix from M'Fouati, Congo. Pierre-Nicolas Schwab collection; L. D. Bayle photo.**

Figure 13. **Cassiterite crystal group, 3.3 cm, from Hunan, China. Frédéric Escaut specimen; L. D. Bayle photo.**

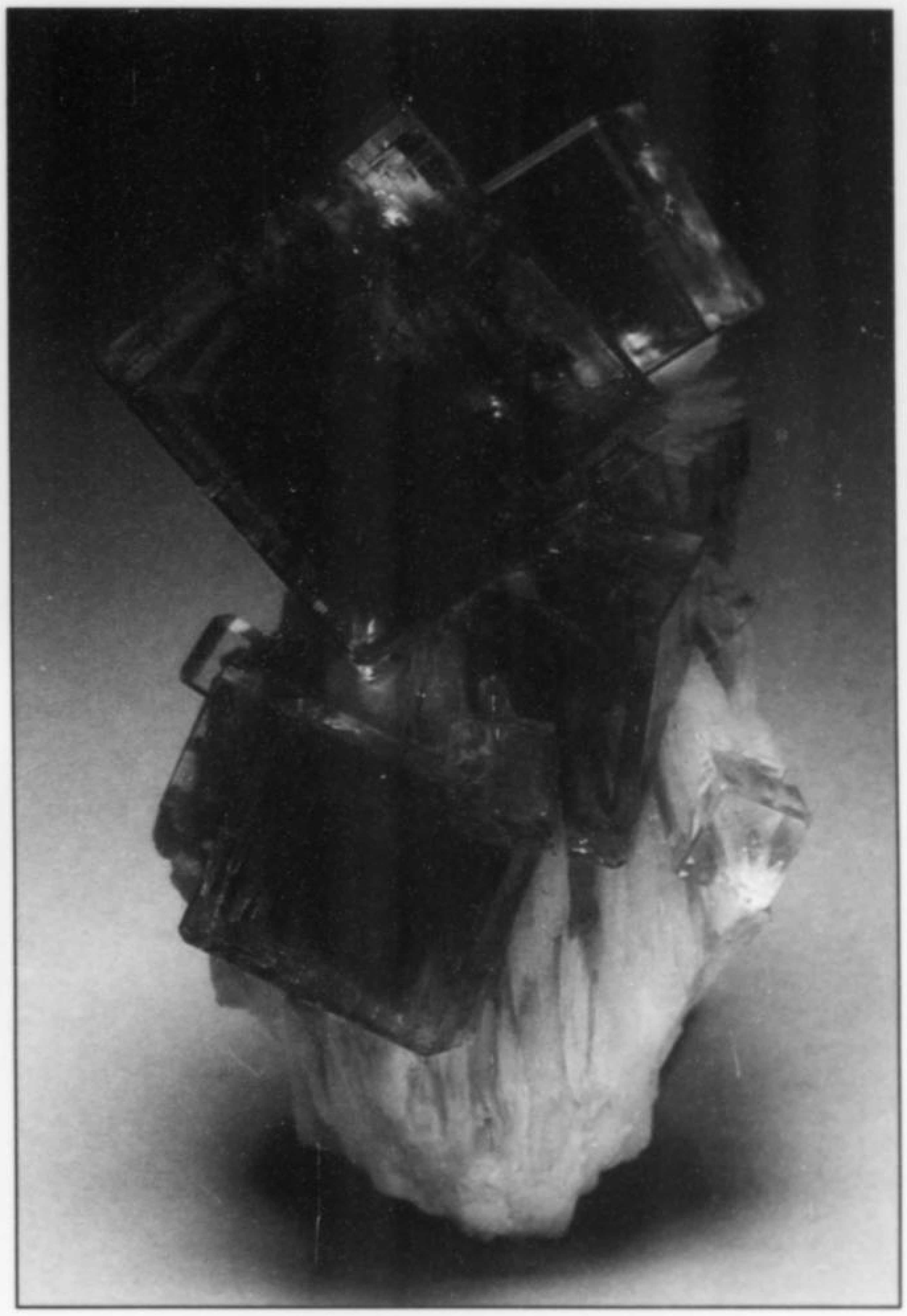


Figure 14. **Fluorite crystals to 1.3 cm, on barite matrix, from Berbes, Asturias, Spain. Laurence Lefévre collection; L. D. Bayle photo.**

in Blum's own *Die Pseudomorphosen des Mineralreichs* (1842). While certainly not the most dazzling case visually, this was probably the *only* place where one would ever get to see, say, a marcasite after argentite from Schemnitz, Hungary (now Banska Stiavnica, Slovakia); or a pyromorphite after galena from the German Schwarzwald; or an epidote after garnet from Arendal, Norway; or a couple of little green dodecahedrons of malachite after cuprite looking exactly like those from Chessy, France, but in fact from the Gumeshevsk mine, Urals, Russia (with a Chessy thumbnail next to them for mirror-image comparison).

Once again, as at Tucson, Jim Bleess assembled a quartz case, and this one seemed to have the thickest traffic of gawkers around it at most times. The loaners of those specimens, great institutions and private collectors alike, can't be thanked enough, but it was Jim's patient months-long work that produced the remarkably successful case. And I do mean success: the case was awarded the Shorty Withers Trophy for "Best Case of Minerals at the Show"; I understand that this trophy is Denver's equivalent of the Ed McDole prize which for many years was awarded in Tucson. The Withers trophy went, specifically, not to Jim himself but to "The Community of Mineral Collectors Contributing to the Quartz Special Exhibit."

Of, goshdernit: it's time to try to come up with a good closing line again. Keep those rocks rolling? Have a nice autumn? Have a nice *day*??? No, I'm outta here, most inelegantly; thanks for reading; goodbye until next time.

Sainte-Marie-aux-Mines Show 1996

by Pierre-Nicolas Schwab

[June 28–30, 1996]

I always wait impatiently for the Sainte-Marie-aux-Mines *bourse*. Firstly it means that I will be on vacation; secondly, this is the only show of major importance that I attend during the year. For those of you who haven't yet come to Sainte-Marie, Alsace is one of the most beautiful regions in France. Moreover it is wine-producing, and many breweries are found here as well (try an Alsace beer and you won't find Bud to your liking anymore). Enough now with Sainte-Marie's charms; on to the show. For this 33rd edition, 460 official dealers came from 35 countries. Such an event is really a challenge, and the always smiling show chairman, Michel Schwab (no, we are not related, although it wouldn't bother me at all), succeeds in satisfying everyone.

This year there were no real new items, but several re-discoveries that produced specimens of interest.

Epidote could well be regarded as a central theme at this year's show. Specimens from various localities were available, but the newest material was on François Lietard's stand. François (*Minerive*, Au Bourg, 42800 Tartaras, France) brought back from his yearly travels in Pakistan some very fine groups from Ashudi, resembling those from Knappenwald, Untersulzbachtal, Austria. The crystals, pistachio-green in color, occur in gwindel-like groups and are associated with asbestiform actinolite. The best specimens measure 10 by 10 cm with translucent crystals to 6 cm.

Many dealers also displayed **epidote** from the Rosario Mabel mine, Mapa Blanca, Castro Virenya, Huancavelica, Peru. The crystals are up to 8 cm in size and are dark green. The special feature of the specimens is that the crystals show both a twin along {100} and a twin along {001}. This material had been bought during the Tucson Show in February. Until recently the locality was only known as "Ica, near Pasto Bueno, Peru." Additional information became available with the closing down of the mine.

Jean François Astier (9 rue Chenoise, 38000 Grenoble, France) also had some **epidote** for sale. As an experienced and successful *cristallier* (mountain man who collects specifically alpine minerals), he discovered them himself in Oisans. With the help of Philippe Cardis (874 chemin des Pècles, 74400 Chamonix, France) he opened a pocket yielding approximately 20 specimens of quartz crystals covered with epidote. The epidote crystals reach 5 cm and are of very good quality. The best and most aesthetic specimen was sold during the show to a German collector. According to Jean-François it was the only one that showed epidote perched on quartz; on all other specimens epidote is growing parallel against quartz.

Another dealer offered **epidote** from Alicante, Spain. Only miniature-sized specimens were available but these are really showy. The crystals are acicular, forming radiating masses in vugs. They are associated with *quartzoids* (quartz crystals showing equal development of the rhombohedrons *r* and *z*) and asbestiform actinolite.

A booth that caught my attention was that of Karl August Cullmann (Mainzerstr. 34, 55743 Idar-Oberstain, Germany), a German prospector. In May, 1996, he discovered a new pocket of **aegirine** on Mount Malosa, Malawi at an altitude of 2,000 meters. Karl explained to me that the pocket is located on the other side of Mount Malosa as it is pictured in vol. 25, page 29 of the *Mineralogical Record*. Actually he has exploited the deposit for six years, and has came to Sainte-Marie every year since then with good material. This year Karl offered aegirine crystals up to 14 cm. It is interesting to note that almost all of the loose crystals are doubly terminated. When on matrix the aegirine reaches "only" 6 cm but is better terminated, sometimes showing the pinacoid {100} and other steep prisms. Aegirine is often associated with **orthoclase** (up to 5 by 10-cm crystals), dark **smoky quartz**, and occasional **zircon** (in yellow gemmy millimetric crystals on orthoclase). The best specimen, a 15 by 25 cm group, had a very nice 5-cm orthoclase Carlsbad twin associated with flawless aegirine crystals to 3 cm. But the best was yet to come. Karl also had several specimens of **eudidymite.** The crystals are loose and up to 3.5 cm in size! Eudidymite had been found only rarely on Mount Malosa and I was pleasantly surprised to see such crystals.

Olivier Szentessy (La Fléchère Quest, 74250 Saint-Jean De Tholome, France) is a French specialist in Australian minerals. This year he brought with him what are probably the finest **crocoites** found for a long time. These came from a new pocket discovered in January under the main fault of the Dundas deposit, at a depth of 60 meters. It yielded approximately 600 specimens and Olivier acquired 400 of them. He washed them in a special chemical treatment and then offered them on the French market. There were a few specimens left at Sainte-Marie, with crystals commonly reaching 2 cm, but Olivier told me that groups a dozen centimeters wide with crystals up to 8 cm had been found (and of course had been sold).

Two French anonymous prospectors displayed a recent find made at the *filon du Rossignol* (Rossignol vein), Chaillac, France. Several species, including the most usual ones, were found at a depth of 255 meters. **Fluorite** was of course well represented, as it is the mineral the deposit is mined for. Excellent specimens with yellowish to brown cubes to 5 cm can be bought for only $100—a real bargain for that French *classic*. However, 7-cm cubes were also available (at a slightly higher price), some of them sprinkled with brown **pyromorphite** crystals. An unusual item was the twinned **cerussite**. This is only the second time (since 1988) that cerussite twins have been recovered at Chaillac. The best example is a 6-cm glassy twin which was unfortunately not entirely flawless. But one of the prospectors assured me that perfect 10-cm twins had been found (they are in his collection). I noticed also some typical **galena** crystals, as well as centimetric "crests" of **barite** resembling those from Saint-Laurent-le-Minier.

For those who like strange things from underground, Alain Carion (6 rue Jean du Bellay, 75004 Paris, France) had the ticket. Alain was back from a trip to the White Desert, Southwest Egypt. He was absent when I visited his booth but his son was kind enough to answer my enquiries. The Carion "team" searched the White desert in December, 1995. They found some quite unusual fulgurites (lightning-generated tubes of fused sand) as well as mineral specimens that were eye-catching. At first sight I thought they were some common marcasite groups, but I was wrong. In fact they are **pseudomorphs of hematite after marcasite**, which is, I must admit, much more interesting! Alain and his son discovered a great quantity of this material, but of a low quality. The specimens which were exhibited all came from a single find made on a few square meters at the base of a peak. Crystals can be up to 2 cm, in very aesthetic groups to a dozen centimeters.

Moroccan dealers are always present in force at French shows, and Sainte-Marie is no exception. This year they brought with them some good news from Touissit: **wulfenite** recovered from a newly dewatered shaft. Two types of specimens were available. In the first, crystals are orange and very bright. In the second, crystals are yellow, up to 3 cm, and associated with cerussite. Unfortunately almost all are broken or of inferior quality. This material was also offered by many European dealers (for example Jordi Fabre) who had previously highgraded out the few undamaged specimens.

A spectacular stand was that of Jürgen Margraf (In der Kofel 4, 82481 Mittenwald, Germany). He had two showcases filled with the best **topaz** and **red beryl** I have ever seen. The red beryls came from an old discovery made in the early 70's in the Wah Wah Mountains. The raspberry-colored crystals reach 3 cm in size, in rhyolite vugs. The crystals are almost gemmy and very lustrous. The best specimen was a group with several centimetric crystals very aesthetically arranged. It was priced at $5,000. Good crystals of any size always run to several thousand dollars or more because of the high gem value of cutable sections, up to $15,000/carat! Now to the topazes. Jürgen found them himself at the Maynard claim. The specimens offered at Sainte-Marie had been mined in April of this year and are doubtless among the finest in existence. The crystals show two different habits: prismatic with predominant prisms, and dipyramids, tabular with well-developed pinacoids $c\{001\}$. Jürgen told me that better material is yet to come for the Münich show.

Chinese minerals were still available in great numbers. Frédéric Escaut (11 rue Félix Faure, 75015 Paris, France) had a good selection. Apart from killer scheelites and gorgeous realgars, Frédéric had something new: *gemmy* **cassiterite** from Yunan. These specimens are truly showy. For the moment we have no further information about the exact locality.

As a **wulfenite** collector I was very pleased to see good material from the Rowley mine, Maricopa County, Arizona. German dealer Werner Radl (Ketterschwangerstr. 12, 87668 Rieden, Germany), had for sale about 200 miniatures and thumbnails very reasonably priced. Some crystals are associated with typical orange mimetite sprays. As usual there were two kinds of crystals: the smallest are orange, the largest bright yellow but wholly gemmy, which is, for crystals of this size, an interesting characteristic. The best specimen is a perfect gemmy twin, 1.6 cm across, perched on a barite matrix. Speaking of which, Maurice Eyraud (*Minerama*, 49 rue de la République, 42800 Rive-de-Gier, France) had a flat of very nice Congoan wulfenites from M'Fouati. They are bright yellow-orange crystals, coated with a thin veneer of drusy quartz, on an iron-bearing quartzite. I noticed a particular specimen with a 3.5-cm crystal showing an unusually well-developed dipyramidal habit. It is really a choice item, as most of the M'Fouati specimens available (at least in French shows) are single loose crystals. Other specimens were available, though smaller.

Lindsay Greenbank (16 Sedbergh Road, LA9 6AD Kendal, United Kingdom) found interesting **fluorite** specimens at Eastgate, County, Durham, England. These are similar to those pictured in the *Mineralogical Record*, vol. 25, page 45. He had also specimens of **boracite** and **hildegardite** presumably found in 1991 at the Boulby Potash mine (see *Mineralogical Record*, vol. 27, no. 3 for further details).

Sainte-Marie-aux-Mines is one of the rare French shows where the systematic collector can find something of interest. This year a rarity was the **poldervaartite** from the Wessels mine, Kalahari, South Africa, on Marcus Budil's stand (Budil & Budil GMBH, Sendlinger Strasse 24, 80331 München, Germany). It is rumored that only 25 specimens have been recovered. If this is true I saw about a quarter of them, as six specimens were for sale. Five of them were sold before the show, but one remained until Sunday. This thumbnail is composed of a dozen white crystals to 5 mm, covered with millimetric quartz grains, and was priced at DM 170.

Giovanni Zingo (34 rue de Vaux, 54610 Mailly-sur-Seille, France) is one of the few French dealers specializing in systematic minerals. I noticed he had a very impressive **ludlockite** with **stottite** from Tsumeb. The acicular crystals form sprays up to 3 cm. The specimen is about 5 cm across, and priced at $5,000.

The Van Vooren brothers (*Genoic*, 8 Henricus Bracqstraat, 9030 Gent-Mariakerke, Belgium) had their usual selection of Canadian minerals, including about three dozen excellent **cubanite** crystals to 4 cm, from Chibougamau, Quebec, Canada. One other item of interest was **wardite** crystals associated with **childrenite** and **eosphorite**, from the famous locality of Rapid Creek, Yukon.

As an old mining town, Sainte-Marie's deposits were well represented all over the show. For example, Gilbert Gauthier (Résidence Les Marquis, 7 avenue Alexandre III, F-78600 Maisons-Laffitte) had a rare **berthierite** from Val-de-Villé (Val-de-Villé is a little village situated 10 km from Sainte-Marie) that came from an old collection (now I regret not having paid attention to the old label Gilbert showed me). He had also an exceptional **monohydrocalcite** from *filon Saint-Pierre* (Saint-Pierre vein). The blue color of this mineral is due to a copper complex that stabilizes the unstable (under normal conditions of temperature) crystal lattice of monohydrocalcite.

Talking with Gilbert, I learned that he had bought exceptional specimens of Belgian **calcite** newly discovered at the Pont-à-Nôle claim, Mont-sur-Marchienne, Hainaut. Unfortunately Gilbert didn't bring them with him to Sainte-Marie, and I had to wait until the Chamonix show a month later. So, on August 10th I met Gilbert once more and saw the specimens he talked about. What a surprise it was! I have seldom seen such quality. Gilbert bought two flats of this material, each containing about 100 miniatures. The specimens were collected with only a chisel and a hammer. This is really a challenge, as calcite is found in Tournaisien formations of very hard entroqua limestone. The crystals, gold-yellow in color, are always twinned along the *c* axis, and can contain inclusions I assume to be pyrite. The best sample (pictured here) is a flawless "butterfly" twin of two scalenohedrons. The crystal is wholly gemmy and measures 4 cm. This piece wasn't for sale because Gilbert planned to give it to the Brussels Museum. It is probably among the finest in the world in terms of quality. Although the other specimens available were of lesser quality, they are still interesting because of the label. The claim is currently being worked for road metal by the Gralex Society. As a consequence collecting is strictly forbidden without authorization.

Back to Sainte-Marie: many dealers (specialized or not) offered **meteorites** in larger quantity than during the previous year. For example Marvin Gillmore (PO Box 95, Payson, AZ 85547) had some very scarce slabs, including a 1908 fall from Czechoslovakia, and little pieces from the Zagami fall (which astrophysicists suppose to come from Mars).

An exhibit featuring the best Saint-Marie specimens was set up near the theater. About 180 pieces were shown, coming mainly from private collections. The exhibition was arranged by themes, such as "Arsenic Minerals," "Silver," and so on. In the "Sainte-Marie-aux-Mines" showcase the best specimen was a 20 by 30-cm group of hematite from Brezouard, covered with centimetric crystals. The "Arsenics" section was doubly interesting, from a historical point of view as the Sainte-Marie deposit was the first and only one to be mined exclusively for arsenic, and also mineralogically as it produced splendid mineral specimens. I particularly liked a 10 by 15-cm group with two arsenic masses to 5 cm, associated with löllingite on a quartz matrix. There were many rarities in the "Cobalt" showcase, among them a fine sainfeldite and the largest skutterudite crystal ever found (both from the Saint-Chrétien mine). Another showcase was entirely dedicated to sphalerite. It contained many fine specimens, but the best one was doubtlessly a 10 by 10-cm quartz matrix covered with dozens of gemmy crystals to 8 mm. The most spectacular was still yet to come, with the "Silver" showcase. Apart from the classical Gabbe-Gottes and Saint-Louis mine wire silver, there were many other rare silver minerals: a fluckite with picropharmacolite, a good rammelsbergite, and also an exceptional prismatic proustite crystal to 1.3 cm on an ankerite matrix. Lastly, another showcase was filled with minerals from the area, such as purple calcite from Lingoutte, fluorite and ankerite from the Saint-Pierre mine. All in all, it was a very instructive exhibition, well organized by Frédéric Latasse and the Old Mines Friends Association.

I had three enjoyable days in Sainte-Marie. But as Mick Cooper wrote in one of his reports, there were too many friends to meet, too many dealers to talk with, and so little time to do it. Next year I will attend the show for four days and it surely still won't be enough. Don't forget to plan a trip to the *bourse*, and see you there in 1997.

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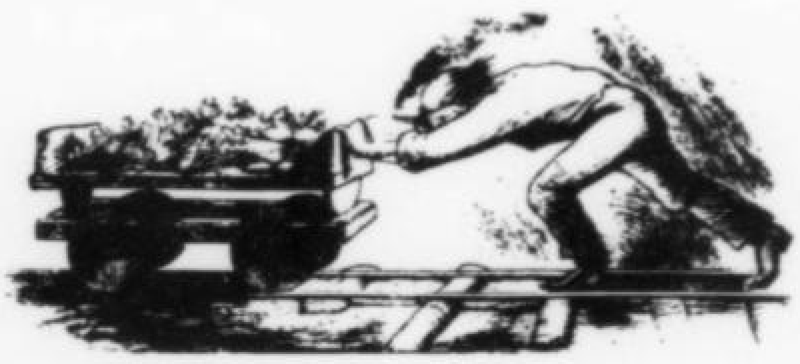

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