Mexico

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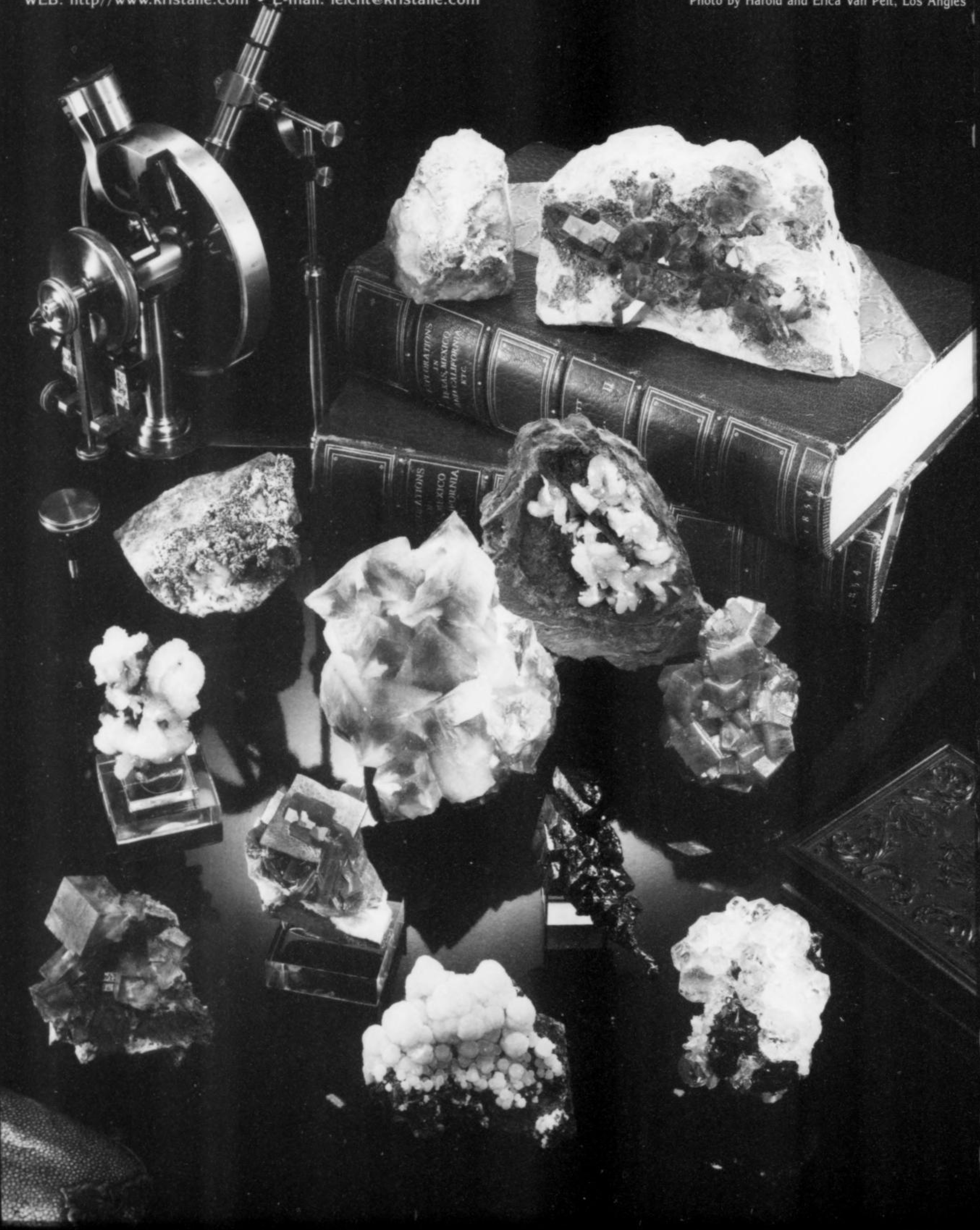
EXPLORATIONS IN TEXAS, MEXICO AND CALIFORNIA ETC.

Mexico

Special Issue II

The Ojuela Mine

History

The Mineralogical Record

❖

September-October 2003 ▪ Volume 34, Number 5

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Front Cover
Purple adamite crystal cluster, 5.4 cm across, from the 1981 find in the San Judas chimney, Level 6, of the Ojuela mine. Houston Museum of Natural Science collection; Wendell Wilson photo.

Frontispiece (page 4)
The mountaintop miners' village and associated head-frames and processing facilities of the Ojuela mine ca. 1900. The famous suspension bridge designed by Washington A. Roebling in 1892 spans the gorge and overlooks the discovery point or *Descubridora* opening below. Photo courtesy of Peter Megaw.

Mexico-II

It has been five years since the appearance of our first issue on the mines and minerals of Mexico (on Boleo in 1998). At that time we issued a "call for papers," hoping that other authors would come forward to help us continue the series. Since that time several people have indeed provided additional reviews of several famous Mexican localities, and these will be published shortly. At the same time, it became clear to us that we could not rely entirely on those papers that were going to come in on their own, so to speak, if we were to produce a comprehensive series. Therefore we began to work on assembling several articles in-house on topics which were not the proprietary favorites of any potential author known to us.

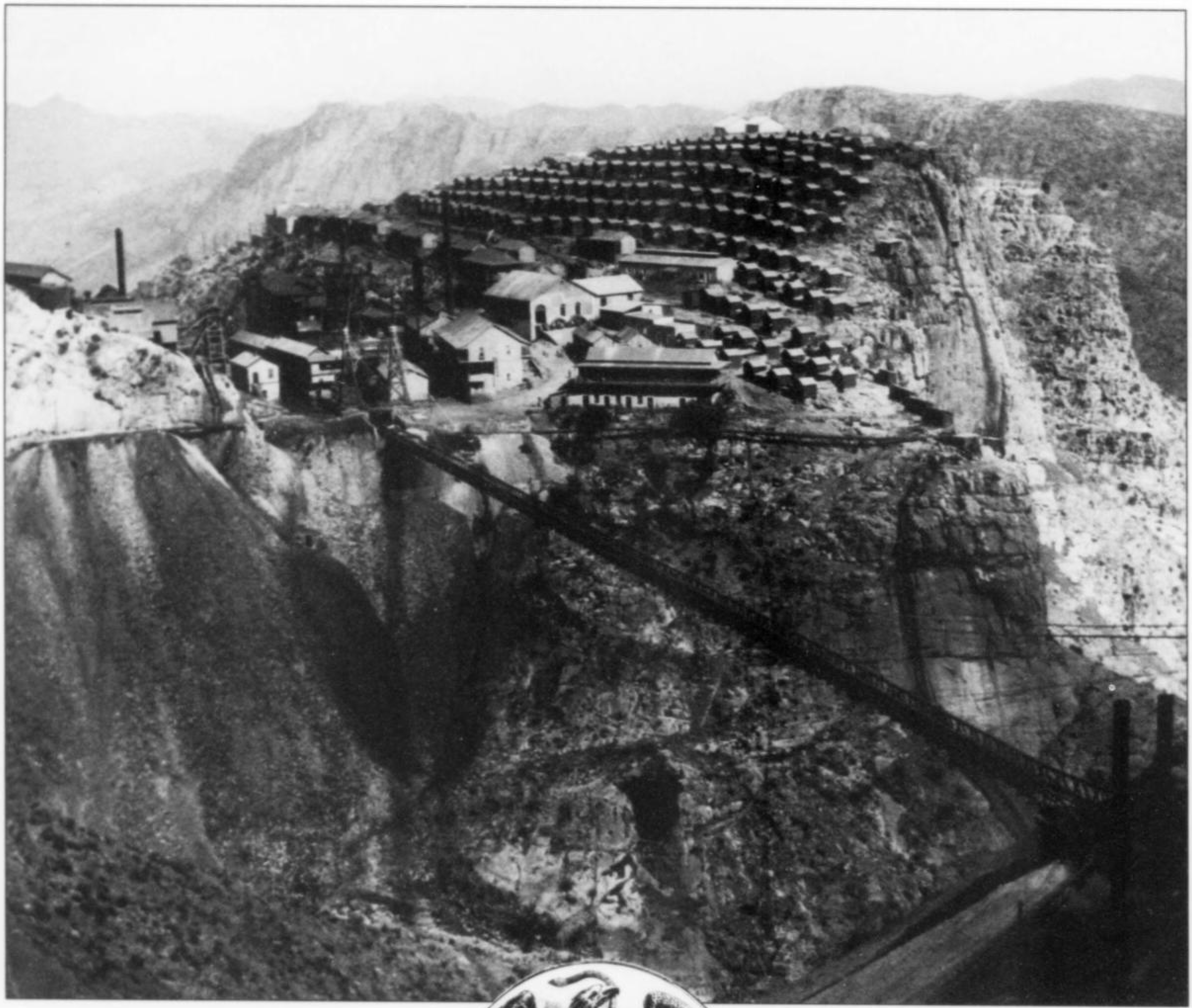
Naturally, one of the foremost of all Mexican localities that came to mind was the Ojuela mine, source of countless thousands of wonderful mineral specimens produced during the last half-century, and at least superficially familiar to virtually every mineral collector in the world. Oddly enough, however, there has never been a comprehensive reference on this world-class locality, save for one obscure and unpublished, outdated, PhD dissertation by Victor Hoffmann (1967) in the archives of the University of Arizona. And so, Editor Tom Moore tackled the daunting task. He has spared no effort in tracking down every scrap of information, published and unpublished, from journals, documents, mineral collections, photo archives and interviews, that could be gathered on the Ojuela mine and adjacent Mapimí deposits; and he spent several days investigating and exploring the site, above and below ground. We are proud to present the result here, which is considerably larger than originally anticipated, thanks to the success of Tom's investigations, and to the generous help provided to him by many people in the U.S. and Mexico. In addition, Peter Megaw, our Guest Editor for this series of special issues and a specialist in the economic geology of Mexico, was kind enough to provide a review of the geology. The generous financial assistance of Mr. Philip Rust was also essential to making this publication a reality, and we truly cannot thank him enough.

Readers hungering for still more on the minerals of Mexico will not have long to wait. Our very next issue, for November-December, will be Mexico-III, covering a selection of several more famous localities and their minerals (including Fresnillo, Las Vigas, Los Lamentos, and others). In addition, the text for Mexico-IV (covering Santa Eulalia, the long-awaited monograph by Peter Megaw) is nearly finished, and we are now turning our attention to plans for Mexico-V. This series will continue until we have covered all of the most important localities.

Readers may be wondering whether we intend to issue these as separate hardcover editions, and I am happy to announce that the decision has now been made to do so, in a limited edition of 300 copies each. In fact, against this possibility we set aside 300 copies of Mexico-I from 1998, which we have just had nicely hardbound, as well as 300 copies of the current Mexico-II issue, and of course we will hardbind 300 copies of Mexico-III in a couple of months. These three books will be priced at $50 each (plus $2 postage each in the U.S., and $4 postage each to other countries), and ***you may order all three at this time*** (Mexico-III will be mailed to you separately when it is ready in November). Furthermore, for all buyers of the three-book set, we will reserve a copy of each subsequent hardbound Mexico issue when it comes out, to make sure that your set will always remain complete. VISA and MC orders are now being accepted while the supply lasts, by e-mail (minrec@aol.com or via our website server at www.minrec.org), FAX (520-544-0815) and regular mail (paid by check, credit card or bank transfer).

But now, as we said when Mexico-I came out, it is time to sit back once again in that comfortable leather chair, prop your silver-studded boots up on the mesquite coffee table, sip your margarita and enjoy another rare reading experience. As the red dusk settles over the quiet desert, you can hear the distant sounds of the miners' pick-axes cutting the limonite gossans in search of pockets, and also the faint tapping sound of us at our computer keyboards documenting it all for yet another special issue. Until then, *buena fortuna* in your personal search for fine Mexican minerals.

Wendell E. Wilson



famous mineral localities

The Ojuela Mine

Mapimí, Durango, Mexico

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with a review of the Geology by
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The Ojuela mine, well known among collectors worldwide, is probably Mexico's greatest mineral locality and surely its most beloved. Discovered by the Spanish in 1598, the deposit was actively mined for 350 years, but did not come to the notice of mineralogists until W.F. Foshag's visit in 1927. Mineral specimens in significant numbers did not appear until the discovery of a huge adamite grotto by Dan Mayers and Francis Wise in 1946. The 117 species now known from the deposit include the world's finest adamite (in a gorgeous array of colors and habits), legrandite, köttigite/parasymplesite, and paradamite, as well as superb specimens of scorodite, hemimorphite, plattnerite, aurichalcite, rosasite, fluorite, calcite, wulfenite and other species. It is also the type locality for paradamite, lotharmeyerite ,metaköttigite, mapimite and ojuelaite, and the co-type locality for scrutinyite. Collecting activity at the mine complex is now relatively small-scale, but good specimens continue to be found sporadically.

Figure 1. **The mountaintop ruins of the Ojuela mine today. The famous suspension bridge is maintained as a tourist attraction. Photo courtesy of Peter Megaw.**

Introduction

The Mapimí mining district consists of a scattering of small mines to the east and south of the town of Mapimí (25°50′ N latitude, 104°51′ E longitude, in north-central Durango State), and one central, great mine. Were it not for this extraordinary mine, the Ojuela, the district would be of little significance for the mineral collector. The other mines, exploiting small deposits of fluorite, celestine, apatite, and magnetite iron ore, have produced few noteworthy specimens. But the polymetallic deposit at the Ojuela mine has proven to be one of Mexico's greatest troves of lead, copper and silver ore—and of crystals of secondary minerals for the collector. Some 117 species are known from the Ojuela mine; it is the type locality for five of them (lotharmeyerite, mapimite, metaköttigite, ojuelaite, paradamite) and the cotype locality for one (scrutinyite).

The Ojuela mine today is a labyrinth of over 450 kilometers of underground workings within the Bufa de Mapimí, a limestone thrust escarpment which begins rising about 2 km to the southeast of Mapimí, then sweeps upwards, striking southeast, to a peak called La Bufa, some 5 km from the town. Large-scale commercial ore mining at the Ojuela ceased in the mid-1940's, but the fame of the mine as a specimen-producing locality has been growing, thanks to the activities of a local mining cooperative, for the past 60 years.

Some like to call the Ojuela mine "the Tsumeb of Mexico," which invites some interesting comparisons. Both Tsumeb and Ojuela are large mines, of immense economic importance in their respective heydays, exploiting hydrothermal polymetallic ore deposits. The Tsumeb deposit, however, is geologically a single huge pipe (of enigmatic genesis), whereas the Ojuela orebody is many times more complex in its structure. The Tsumeb mine is only 100 years old, whereas the Ojuela mine is 400 years old; but Tsumeb produced specimens for the collector market throughout its 100-year history, while Ojuela has done so only during the last 60 years, *after* ore mining had largely come to an end (we almost dare not think of what extraordinary specimens the miners probably encountered and crushed as ore or discarded as waste during those 340+ years). Both localities are noted for their rare species, their abundant specimens for the micromounter, and their world-class examples of several major minerals. But the Tsumeb deposit, with its simpler geology, exhibits more complex mineralogy: roughly

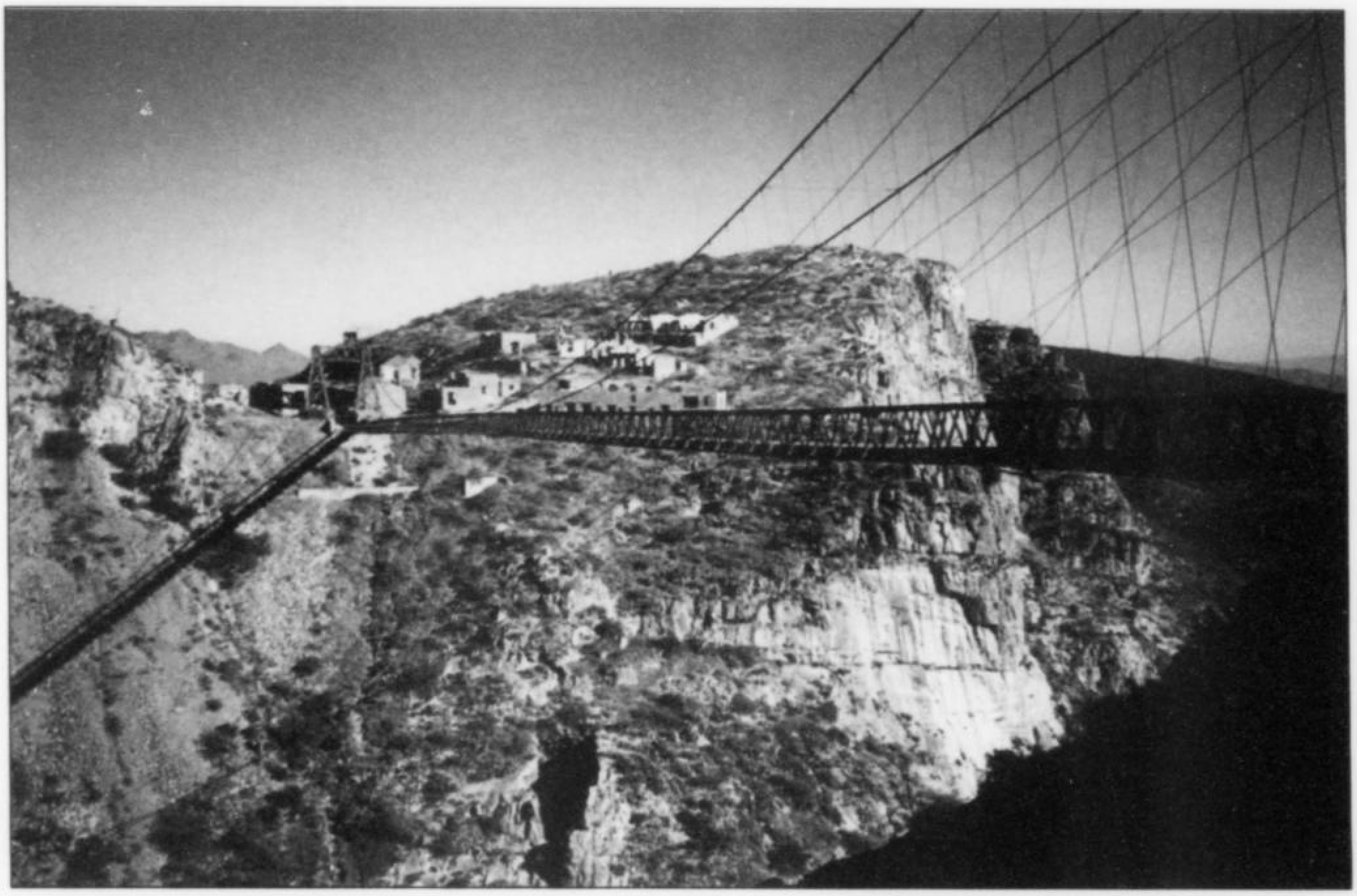


Figure 2. **Recent view of the miners' village, the Roebling bridge, and the discovery hole (bottom center), seen from South Camp, November 2002. T. Moore photo.**

250 Tsumeb species are known, whereas Ojuela offers only half that number. Around a dozen major Tsumeb species attain world's-best status, and for Ojuela the number is likewise about half that. Nevertheless, the most revered of the classic specimens from both localities are very beautiful and utterly distinctive. Experienced collectors today will have grown up regarding both localities as familiar sources, and acquiring immense respect for both—so there is ample justification for thinking of the Ojuela mine as the "Tsumeb" of the Western Hemisphere.

Bancroft (1984) lists three possible derivations of the name "Ojuela": perhaps the mine was named for a long-ago missionary, one Don Pedro de Ojuela; perhaps it was named for a hole resembling the eye of a needle (*ojuela*, "little eye") visible at one point on the mountain above the mine; or perhaps the name derives from *hojuela*, an old Spanish mining term for argentiferous galena of a leafy texture. The needle-eye hole near the peak of the Bufa de Mapimí is clearly visible from a certain vantage along the road into Mapimí, but, for what it is worth, the present miners seem sure that the leaf-ore etymology is the correct explanation for the mine's name. Indeed it is easy enough to imagine the first cries—something like "*hojuela, hojuela!*"—at the first sight of a leafy lead-gray metallic outcrop, when the first party of adventuring Spaniards rode their horses up the echoing, pristine canyon in 1598, the official year of discovery.

Somehow the region encourages such fantasies. The approach to Mapimí from the north runs through plains spotted modestly with scrub vegetation (huizache, candelilla, sangre de dragon—"dragon's blood," with vivid red excrescences along high, dry, thin stalks), but no visible human habitation. Moody-looking ridges mark the horizons around a vast flatland which, as even a roadside sign respectfully notes, falls within a "Zone of Silence" (this zone extends from the Bolson de Mapimi to the Big Bend area of West

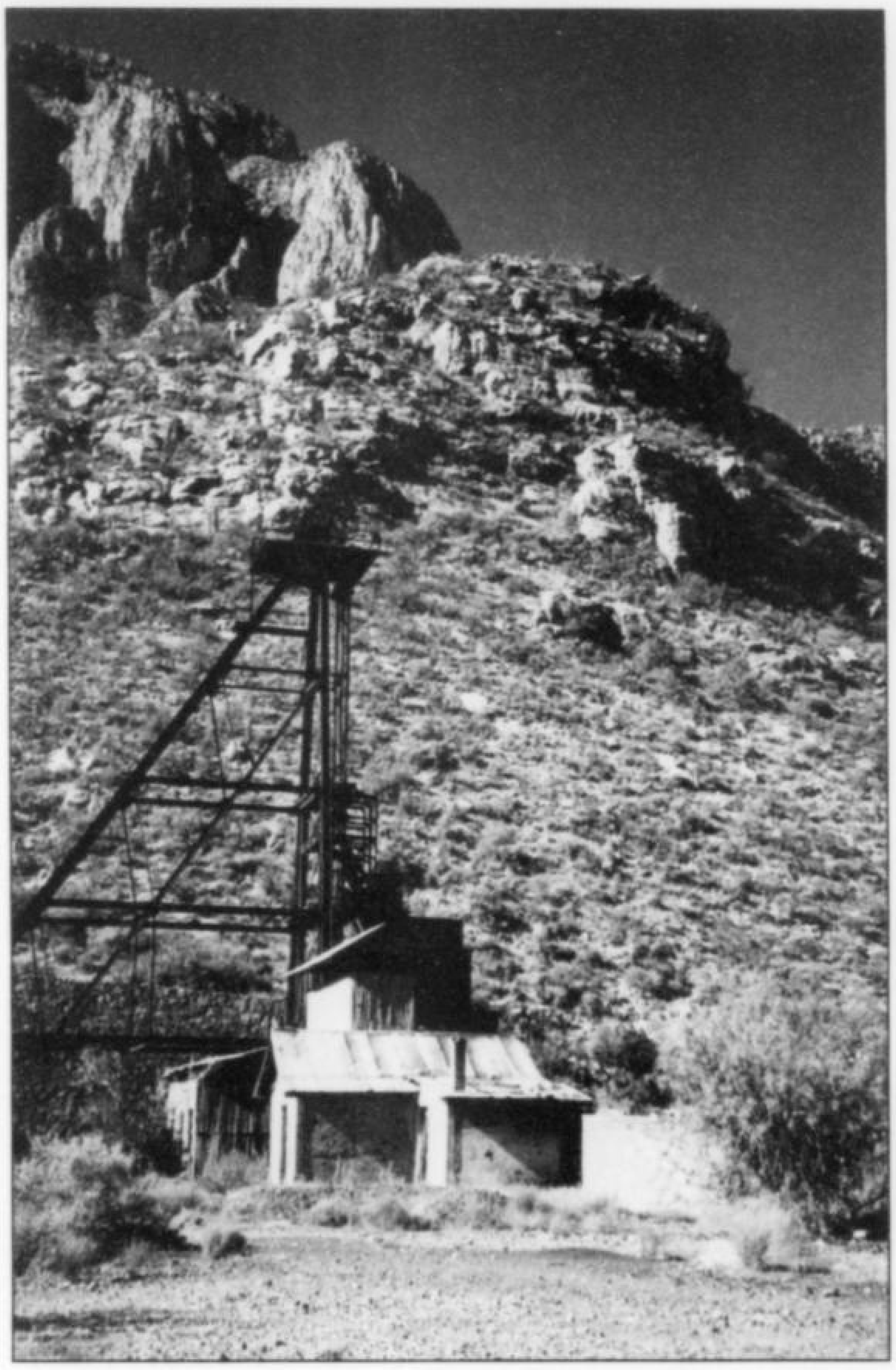


Figure 3. **Headframe of the America Dos (Tiro 2) shaft, in the valley northwest of the miners' village, November 2002. T. Moore photo.**

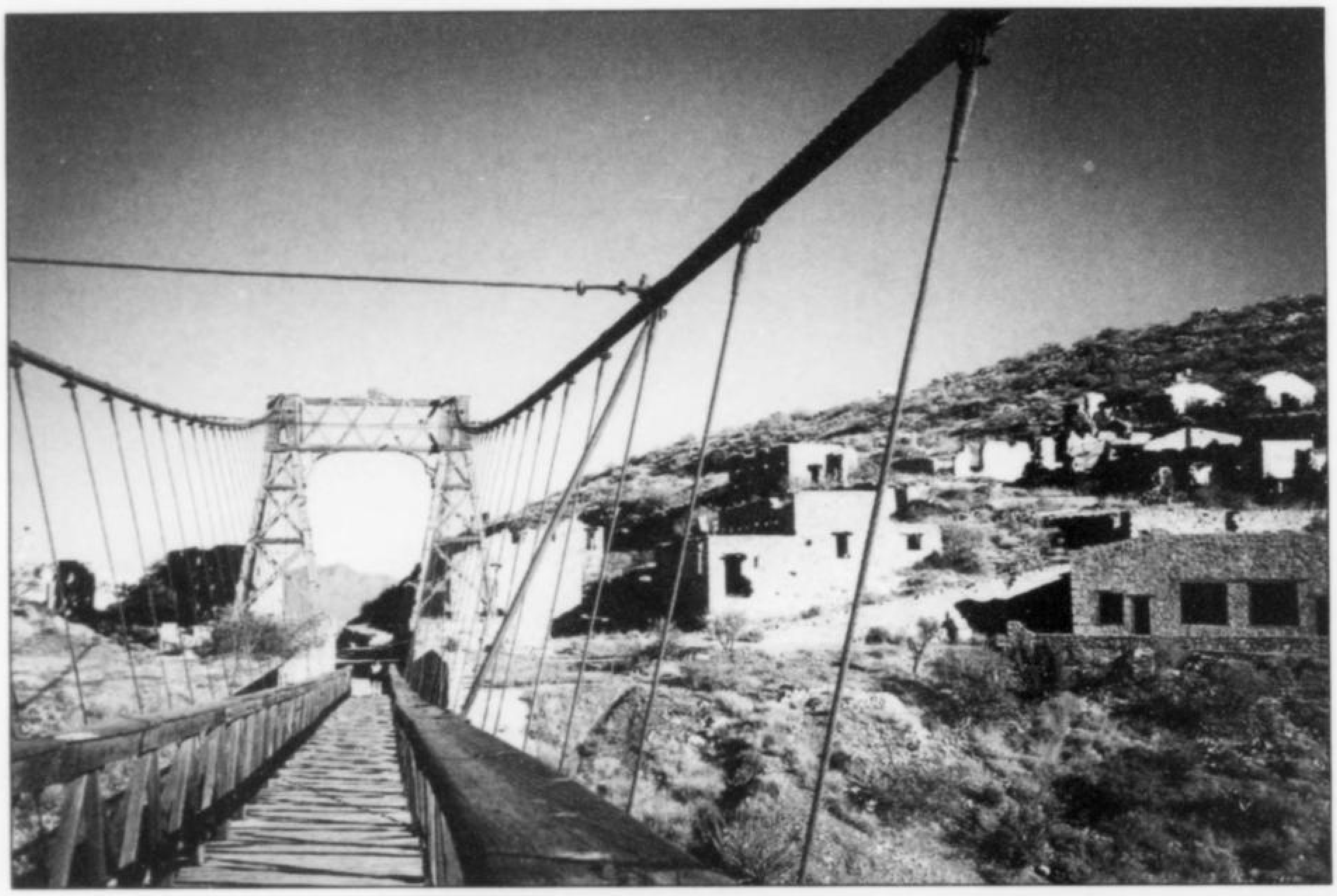


Figure 4. **Crossing the Roebling bridge to the miners' village, November 2002. T. Moore photo.**

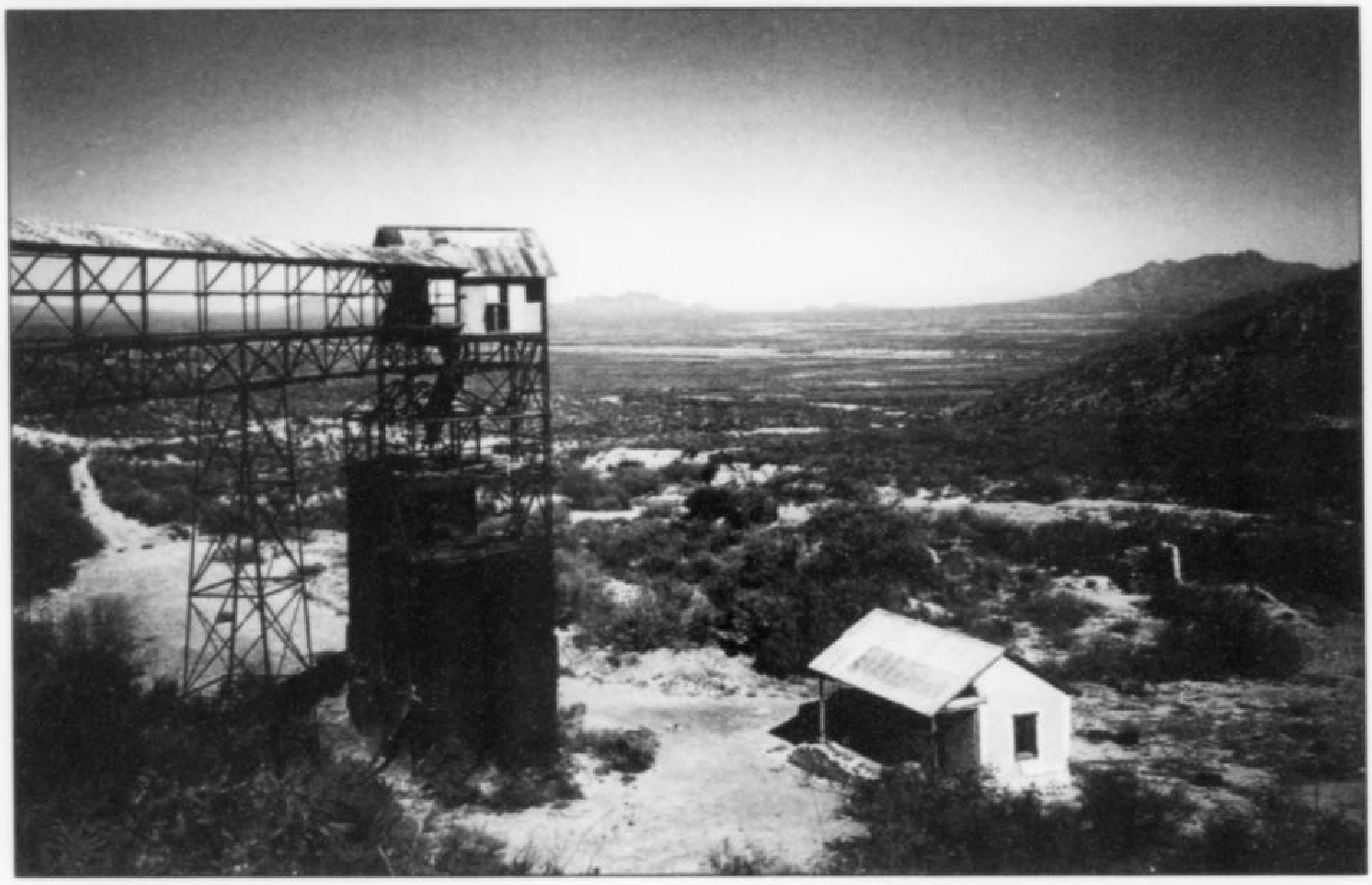


Figure 5. **America Dos (Tiro 2) shaft and miners' shack in the valley north-west of the miners' village, November 2002. T. Moore photo.**

Texas). Wild peyote grows on hillsides, and it is said that shamans and medicine men are about; some locals believe that extraterrestrials secretly gather here, or that meteorites fall more often on these brown pavement-wastes than in other places.

At a point on the southern edge of this vaguely mystical Zone, the town of Bermejillo hugs both sides of the road but does not extend laterally: it is a weary double strip of grocery stores, bars, little restaurants, and bus stops, with trucks and great cargo vans parked two-deep all the time (no doubt because the road is a toll-free alternative to a main north-south highway). But there are past glories that could be sung—the Battle of Bermejillo was a major victory for Pancho Villa's revolution, and in the heyday of the Ojuela mine the town was a busy railroad loading-point for ore and bullion.

At Bermejillo a two-lane blacktop road, Mexico Route 30, turns due west, then runs for 24 kilometers along the valley to Mapimí. A few kilometers to the south of the road, a silhouetted part of the Bufa de Mapimí may be seen; it is known as "La India," as it resembles the profiled face of an Indian woman asleep, dreaming into the sky; and the miners give firm assurances that certain patterns of ancient raindrops preserved on a shelf of limestone beyond La India's headdress are the footprints of one or more of her lost and wandering children. Less romantically inclined visitors might notice instead the many chicken-farm buildings strung all along the valley for many kilometers on both sides of Mapimí. A substantial percentage of all the frozen chickens processed and packaged for Mexicans and *Norte Americanos* alike by the Tyson's Company are raised here. When things are slow in the mine, some miners get part-time jobs slinging live chickens by the handful (one pair of chicken legs between each pair of abrading fingers) into sacks, and soon the chickens are poured into cages, and these cages

Figure 6. **Former Mapimí dance hall, now being used as a storage facility for recently mined mineral specimens. The gold-painted bust in the foreground depicts Mexican Revolutionary hero Pancho Villa. November 2002; T. Moore photo.**

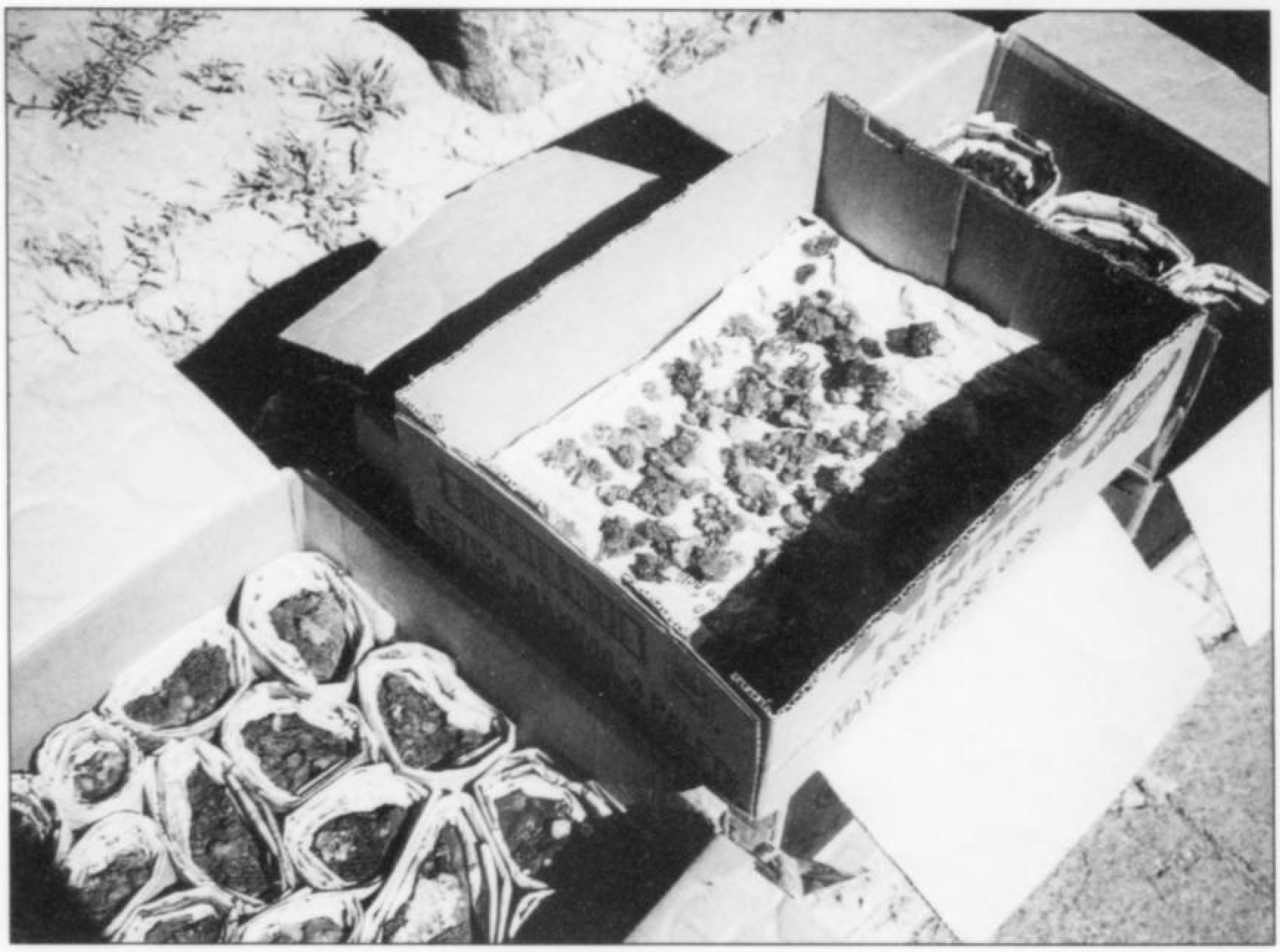


Figure 7. **Adamite specimens just collected from the San Judas chimney and ready for sale at the Mapimí storage facility, November 2002. T. Moore photo.**

are to be seen stacked ten-deep on flatbeds of the chicken trucks that seem always to be plying the Bermejillo road.

A few kilometers before the outskirts and fringing palm trees of Mapimí (the ruins of the old ore smelter are seen off to the right in the middle distance), a sign marks the turnoff for the Ojuela Bridge: the great structure built in 1895 by John Roebling, Inc., New York, which was for a while the second longest suspension bridge in the world. At the road intersection, two colorful rock shops wait hopefully for tourists, and a man stands ready to lift a gate to give access to the bridge road. After a short distance a cobblestoned surface begins, and the road's grade increases: this is the former bed of the cog railroad which ran for 4 kilometers from the valley to the upland, where the major mine workings were, and where the mine workers lived.

At the crest of the cobblestone road a wide clearing opens. A slope rising on one side of the clearing bears a few scattered adobe-and-woodbeam ruins: the "management" part of the old miners' compound. Another rise on the opposite side, with only the scantiest of ruins, is the site where common miners and their families once lived, in a village which, at its peak, held over 5,000 people. Looking between the massive bridge abutments, one sees the precarious thrust and soar of the bridge as it spans the canyon, and beyond it on the other side the entrance to the #4 shaft (once called the Socavon shaft) far away on the opposite end. Walking out onto this spindly structure is not an experience to be recommended for acrophobes, who will be distressed to feel the deck swaying lazily under their tread. From the bridge's midpoint, looking far down, one can see the black opening of the *boca mina*, or *Descubridora* ("Discovery") hole, near the floor of the canyon beneath the miners' village. At the other end, one arrives at the opening of the #4 tunnel; very near it is a bottomless glory hole, and directly off the bridge one passes over a steel grating sealing

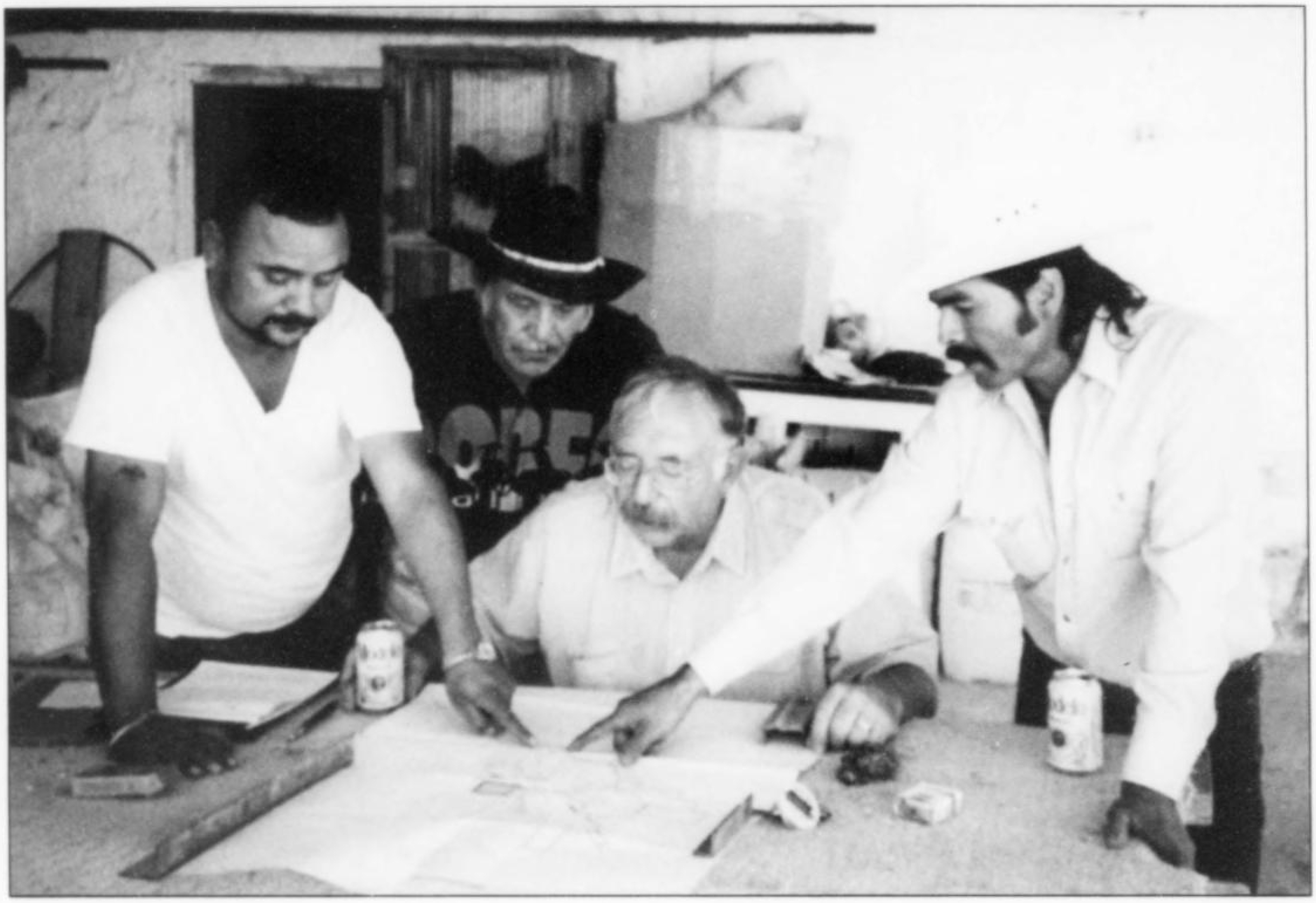


Figure 8. **Former miner Lazaro de Anda (left), who is also an agent for *Top Gem Minerals*, and *Top Gem* Chief Miner Federico Salas Alzarado (right) point out locations of *lugares* on a large claim map of the Ojuela mine while Antonio Briones looks on. Mike New, a partner in *Top Gem Minerals*, is at center. November 2002; T. Moore photo.**

the mouth to another bottomless hole. There is a story that once, in the 1970's, before this hole was sealed, a woman fell to her death here, just managing to toss her infant child to her husband as she toppled off the treacherous collar into the shaft. Today, short guided tours into the #4 tunnel are available to the tourist, who may also buy a souvenir mineral specimen or a cold drink from the vendor at a jerrybuilt wooden stand here (the specimen is likely to be a barite rosette or a piece of agate from somewhere in Chihuahua or Brazil). This vantage offers a good photo opportunity: the best view of the total span of the bridge and of the symmetrical bluffs of the miners' village behind it, with the black maw of the *boca mina* on which to anchor the viewfinder.

Mapimí itself is, of course, a mining town, and offers a small mining museum, where you may see rows of old photographs on the walls, and glass cases displaying old tools, artifacts, and documents (sorry, no mineral specimens) preserved from the great days of mining. Mapimí also features a small baroque church, a palm-lined plaza, dirt streets with blue-and-white houses, loose dogs, and road-pummeled pick-up trucks in the dusty sunlight. Visitors who penetrate sheltered courtyards may find well-tended fighting cocks in wire cages. The miners of the co-operative organization often gather in a small plaza near the east end of town, with an old dance hall on one side and a gold-painted stone bust of Pancho Villa on the other. The dance hall now serves as a storage facility for newly mined mineral specimens. The miners, young and middle-aged men who, on typical evenings, socialize in this plaza, are mostly brothers or cousins; there are a few restless children about, but no women. The talk is of town life, food and drink, work and wages, the legends of Villa, and the new adamite and aragonite just emerging from a promising zone deep in the San Judas chimney. Great good fellowship in the plaza even extends to the guest who may not understand many words of the language.

For several decades now the miners' main access to the vast underground workings of the Ojuela mine has been through tunnels near the America Dos shaft. The old headframe here is a prominent landmark in the valley, and the remains of ore dumps around it could furnish much happiness to micromounters even today. But there are many other openings to the tunnels and stopes of the old mine, and collecting is now going on in that deep zone in San Judas, at a level so difficult of access that it takes the miners more than two hours to climb down 700 meters of ladder to the collecting area. *Riscos,* treasure, is the miners' term for crystals, and treasure-seeking is now the specialized order of things in Mapimí. But at one time, of course, the treasure was ore, and crystal specimens were mere stowaways in the great ore tonnages that emerged from the #4 shaft, to be transported on burros' backs and by cogwheel trains down to the valley. The following section describes this floodtide time at the mine, during the decades around the turn of the 20th century, and the trickles of activity in the decades on either side of it. This is a story of conquistador explorers followed by civil wars and confusions, and these, in turn, by grand-scale industrial capitalism, culminating at last in the humbler hunt for the kind of *riscos* which *Mineralogical Record* readers enjoy.

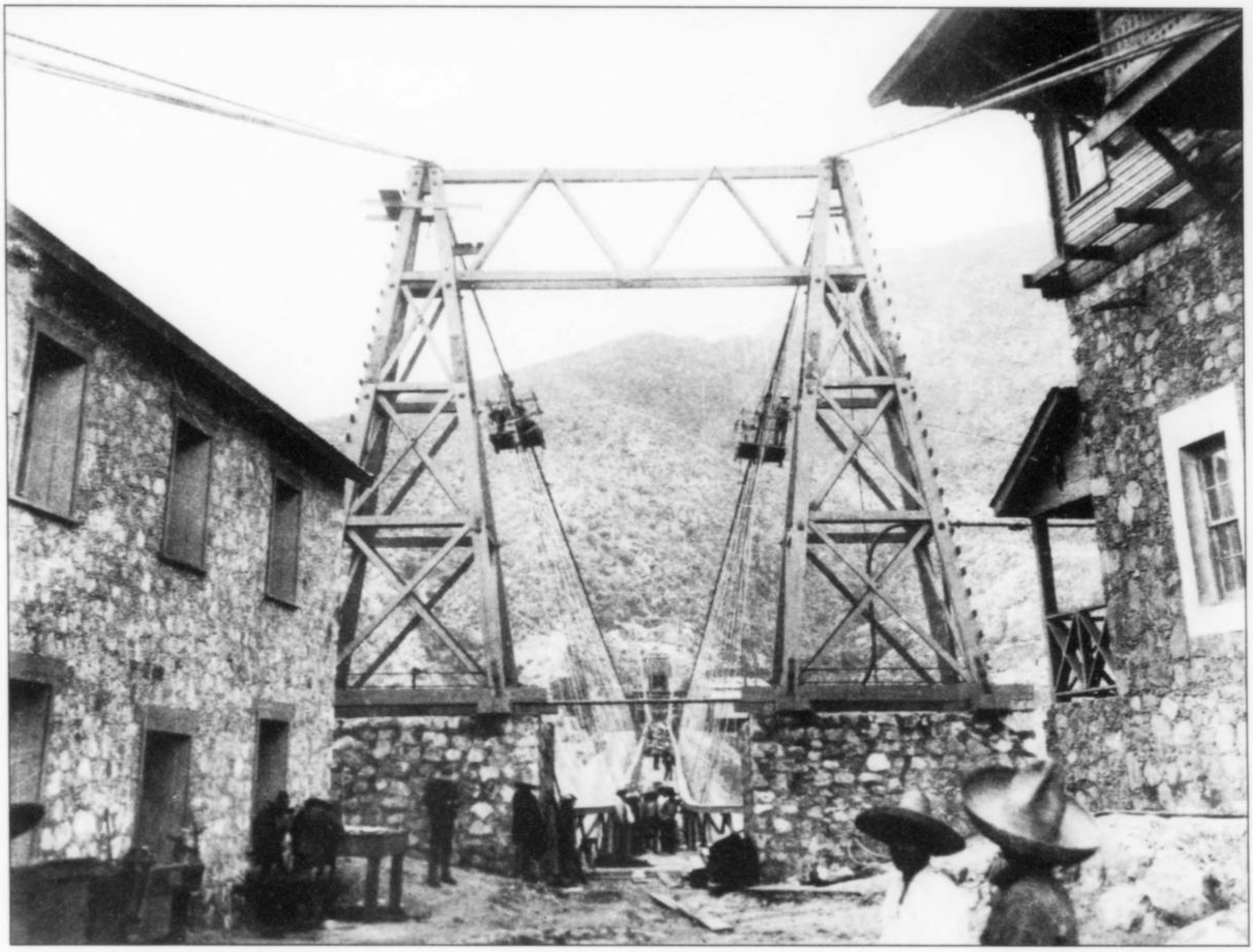


Figure 9. **Towers of the Roebling suspension bridge at Ojuela (miners' village side) shortly after construction was completed in 1892. Photo courtesy of the Mapimí mining museum and Brad van Scriver.**

History

Spanish Beginnings

Metal mining in Mexico began with the 16th-century Spanish *conquistadores* and their treasure-seeking heirs. Although there are some signs of rudimentary mining activities in the country by early native American peoples before the Spanish conquest (Waszkis, 1993), even these traces are confined to regions south of the present state of Durango—the domains of the Aztecs—while for the wild north the record is totally silent, even in legend, until the Spanish incursions at the end of the 16th century.

The earliest, small, Spanish silver mines in Mexico were at Sultepec, Michoacán, Zacualpán, and other sites near Mexico City; the first large mine on a major lode was opened at Taxco, Guerrero, in 1534. The subsequent "silver rush" northwards took only a couple of generations and, before it was spent, reached territory well north of Mapimí: nearly every silver deposit so far discovered in what is now the southwestern United States bears traces of Spanish mining activity. This headlong northward rush left a trail of exploratory workings, failed prospects, and vague memories. One founding myth has it that the town of Mapimí sprang up in part because of a natural spring on the site (the town later became a main watering place on the route between Mexico City and Chihuahua), and because the Ojuela ore deposit was discovered there by Spaniards in 1598 (Rice, 1908).

Through the Discovery Tunnel, the Spanish mined the deposit for silver until their departure in the 1820's, smelting the ores "with great success" (Rice, 1908) in adobe furnaces. Although pertinent records are practically non-existent, it seems safe to say that during the colonial period the Mapimí mines contributed largely to the general success of silver mining in New Spain (Mexico). These New World operations often employed the latest European techniques; e.g. the use of gunpowder for underground blasting was introduced in America only a few years after its development in Europe. And Bartolomé Medina's "patio process" for the amalgamation of silver ores vastly increased production after 1555, when Medina invented the process in southern Mexico (the process, however, was not used in Mapimí).

The mining *Ordenanzas* of 1783, the so-called New Code of Charles III, was "the most complete mining code compiled by any nation up to that time" (Bernstein, 1964), and 1792 saw the founding of the Mexican School of Mines, the first technical school in the New World. A final great boom of Spanish-Mexican silver production took place in the two decades just before the Wars of Independence (1810–1821), with Mexico producing between $20,000,000 and $25,000,000 in silver and gold annually (Jenison, 1923a)—a 5-fold increase from a century earlier (Bernstein, 1964).

Figure 10. **Constructing the deck of the Roebling suspension bridge, ca. 1892. Photo courtesy of the Mapimí mining museum and Brad van Scriver.**

But working conditions in these mines were brutal from the earliest Spanish days, when mining had significantly contributed to the depopulation of aboriginal peoples. Miners carried ore out of the workings in loads of up to 200 pounds, in bags of leather or *ixtle* fiber which hung at their backs from straps secured across the forehead. Still to be seen today are the remnants of the long series of steps hewn into the limestone of the Bufa de Mapimí, where these miners ascended, bearing their loads, along the canyon walls; the cog railway later built here had to traverse grades of up to 14%. Although silver mining in New Spain had done much to remake the world economically and politically, and had provided the prime impetus for the development of modern Mexican civilization and culture, it left behind a largely unwritten history of pre-industrial misery.

1820–1876

In 1810 Napoleon invaded Spain, the New World colonies felt themselves ripe for freedom, and in Mexico the War of Independence broke out. The widespread anarchy, vengefulness and destructiveness of this war, which lasted until 1821, made a wasteland of the country, and brought disaster for the mining industry. No records of events specifically at Mapimí are available for this period, but the general picture is clear: in the account of H. G. Ward, British chargé d'affaires in Mexico in the 1820's, "The civil war destroyed the . . . machinery and works of the mines themselves . . . [and] mining towns were surrounded by insurgent parties, which occupied the whole of the open country, and rendered it impossible either to receive supplies or to make remittances without the protection of a large escort" (quoted in Jenison, 1923a). Mines collapsed, roads fell into disrepair, prospectors stopped working, and most of the Spanish and Creole mine owners either were killed or were expelled from the country by the new government. Remaining mine owners and managers found that many mines which had yielded a profit under peon labor could not survive with properly paid workers. Between 1810 and 1821, the yield of the Mexican mines fell from $27 million to $5 million yearly (Dahlgren, 1883).

Around 1825, the new Mexican government decided to abandon Spanish precedent and seek foreign investment, inviting governments and private entities in Europe (excluding Spain) and in the U.S. to develop Mexican mines. Most of the early money was British, thanks to the promotional skills of an anglophile former Guanajuato miner, Lucas Aleman, who had spent the years of the war in self-exile in London and was now the first Foreign Minister of Mexico. This early investment came in a surge which Dahlgren (1883) calls the "Great English Excitement" of 1824–1834, when, through Aleman's efforts, the British United Mexican Mining Association was capitalized for £1,200,000. Persisting until the start of the 20th century, the Association controlled numerous mines and smelting works in Sonora, Chihuahua, Durango, Zacatecas and Oaxaca (Graham, 1907). However, even during the decade of the Excitement, shareholders sustained immense losses, mostly because there were no railroads in Mexico, and heavy machinery and ore could only be moved on the backs of mules. Aleman's party fell from power in 1837, and he had to go into hiding for a few years; in 1840 he opened a cotton factory, which soon failed.

Other foreign investments in Mexican mining during this period proved evanescent. Commitments of capital by the assorted parties clearly were premature, though the parties themselves come across in the literature as colorful and even romantic: a group of Scotsmen worked a surface bonanza at the Rosario mine in Chihuahua, operated a mint, and hauled Cornish mining machinery into the country; French capital came in via a Parisian banker named Oecker, who worked many mines but "wrought untold havoc, [advancing] loans at usurious interest to the government . . . some say that Oecker was shot by the commune in Paris in 1871" (Graham, 1907). A German organization, the Eberfeld Mining Company, briefly held properties in Hidalgo and the State of Mexico. One early U.S. company, the American Mining Company, operated at Temascaltepec in the 1820's but "had only a brief and troubled existence" (Graham, 1907).

During these decades, parts of the country, especially in the north, were terrorized by outlaw bands who exacted tribute from the mining companies and anyone else who could pay it (Jenison, 1923b). Roads were still largely lacking in the interior, and in the wilder northern regions there was trouble with Comanches and Apaches. Continued political instability, then the 1846–1848 war with the United States, then the French intervention of the 1860's, all conspired to suppress Mexican mining through most of the middle decades of the 19th century.

Another factor inhibiting progress was the by-now outdated state of Mexican mining technology. Spanish methods which had worked well enough for easy, high-grade ores in near-surface deposits proved inadequate for exploiting the deep-seated, lower-grade ores which remained. The ores of the Ojuela mine make a good case in point. These deposits consist of structurally complex mantos and "chimneys" of polymetallic ores; the orebodies which emanate from the larger structures wind like pasta noodles through fault-

Figure 11. **The Peñoles cogwheel train carrying miners and ore sometime in the 1890's. Photo courtesy of the Mapimí mining museum and Brad van Scriver.**

gouge and other zones of greater permeability to mineralizing solutions, in highly folded and faulted limestone (see under Geology). The intricate system of shafts, stopes and adits for mining such a deposit was already well developed at the Ojuela mine by the mid-19th century, but local mining methods, long cherished and in their ways efficient, were necessarily slow, and the Mexican miners were resistant to change. The men would gopher into tiny, irregular stopes with long-handled hoes and iron scrapers; with these they would dislodge the soft oxidized ore from the vein, then sweep it into small pans, to be loaded into the immemorial rawhide sacks to be carried out on the miners' backs (Rice, 1908a). "Chicken ladders," primitive winzes, and other hallowed technologies complemented the hoes and scrapers. Indeed, to this day, visitors to the underground workings will find, and must often use, these chicken ladders: simple notched logs, "much scorned" according to Rice (1908a), but held dear by the stauncher traditionalists among Mexican miners.

Laws governing mining and mining finance during this period were also ineffective, in fact contradictory and incoherent. In 1842, the Mexican government passed laws expanding the rights of foreigners to acquire and run mines, and encouraging exploration; as a result, the production of silver in Mexico during 1841–1850 was one-third again higher than it had been in the preceding decade—though still nowhere near what it had been during the final decade of Spanish rule (Bernstein, 1964). At the same time, however, federal and local taxation on mines kept increasing, and any remaining profits of the mine owners were often expended in paying tribute to bandits. A constitutional change in 1857 permitted individual Mexican states to legislate on mining matters, and tax burdens were thereby further increased. Operating decisions made by boards of directors in Europe or by their agents in Mexico frequently "demonstrated a folly, extravagance, and incapacity which became matters of constant amazement" (Bernstein, 1964). By 1867, the mines of the Mapimí district, like many important mines throughout the country, had been almost abandoned. But modern enterprises such as the Compañía Minera de Peñoles, S.A., under a new political regime, were soon to bring on a golden era of Mexican mining. It is during the 20 years or so preceding the birth of the Peñoles Company in 1887 that the history of the Ojuela mine comes into focus at last.

1876–1910

In November 1876, General Porfirio Diaz was elected President of Mexico. He held on to the office (by whatever means) until 1910, and during that long reign he profoundly modernized Mexico, in mining as well as in other areas. For a personality sketch, and a summary of some achievements, of this remarkable chief executive/dictator see Bariand *et al.* (1998).

Diaz' first priority for the mining industry was to tighten its federalization, reducing the regulatory powers of state and local governments and lightening arbitrary, corruption-riddled tax assessments on the mines. His second priority was to encourage and smooth the way for foreign investment on a scale vastly greater than in the earlier period. U.S. and European interests were assured that any investments they made would be safe; the federal government of Mexico would guarantee investors' titles of ownership in perpetuity if they would pledge to remit taxes to the Mexican treasury on simple, transparent terms. New mining laws passed in 1884 and 1886 revised the earlier tax codes with the effect of greatly reducing the overall tax burden for foreign companies. A code passed in 1887 empowered the President to make special contracts with mining companies willing to invest not less than $200,000 within five years. By 1895 there were about 40 American companies operating in Mexico, mostly in the northern states (Waszkis, 1993). Conditions still being somewhat wild in the north particularly, Diaz also saw to building many more roads and railways into the interior, and to reducing the danger from Comanches, Apaches, and outlaw bands. Near the end of his rule, it could plausibly be written that Diaz had "turned his attention to civil matters [so effectively that] Mexico today affords more protection than many of the states of [the United States]" (Graham, 1907).

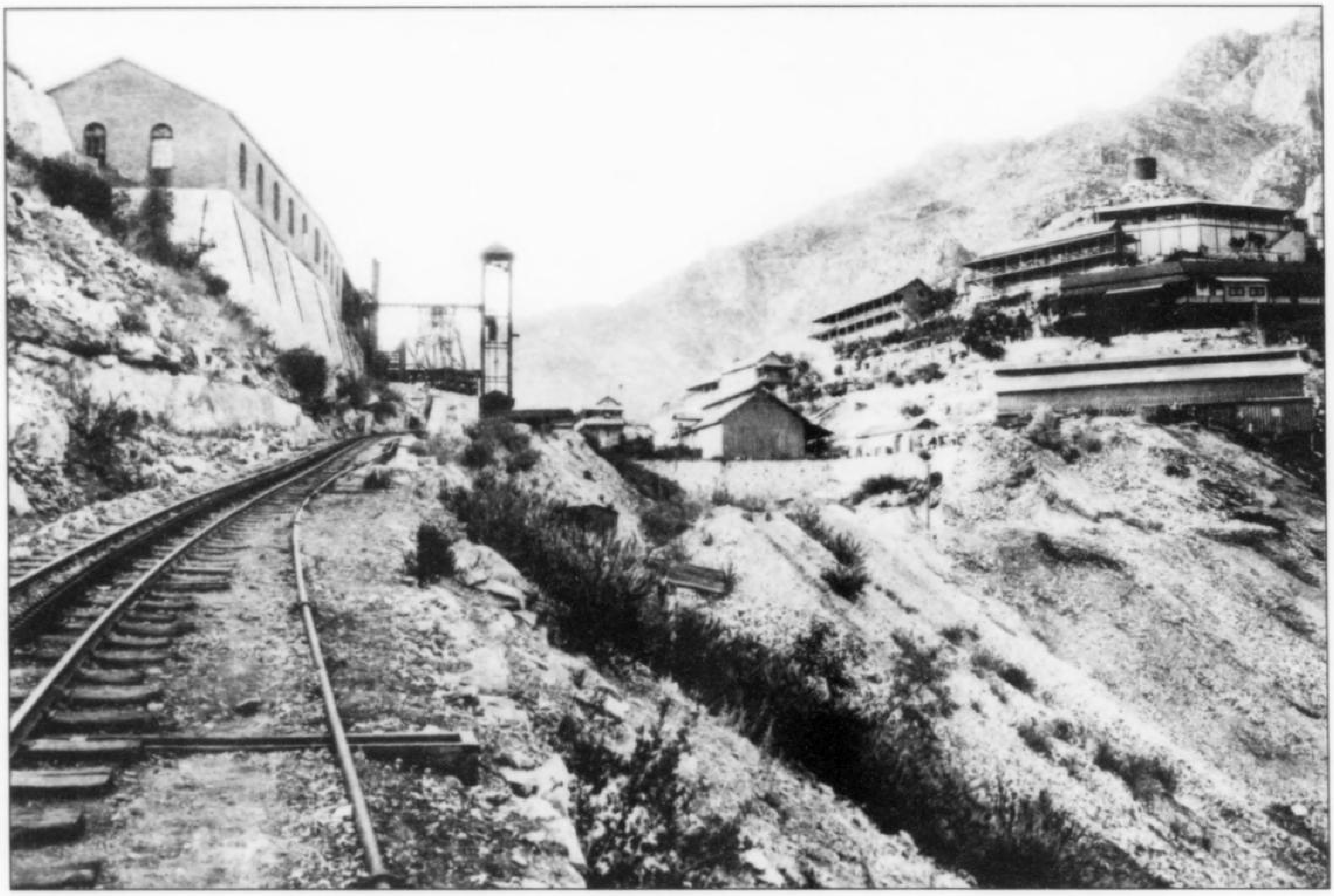


Figure 12. **Cogwheel train track approaching the Ojuela miners' village sometime in the 1890's. Photo courtesy of the Mapimí mining museum and Brad van Scriver.**

The Diaz government also encouraged foreign capital to invest in infrastructures to broaden the scope and potential of mining. The most important of these were railroads, and the next most important were ore smelters. Up to this time, most Mexican ores had been shipped to the U.S. for smelting, and the freight charges had made the lower-grade ores unprofitable, but now, as copper and lead mining joined silver mining, it was clear that smelting as much ore as possible in-country would profit everyone. The lead was taken by the Guggenheim family of the United States: having grown rich from mining investments in Colorado and having built their own ore smelters there, the Guggenheims first began importing silver ores from Mexico, then soon decided to lease mines in Nueva Leon and Jalisco and to build smelters in Monterrey and Aguascalientes to process the ores. A series of capitalistic maneuvers enabled the Guggenheims finally to gain control of the American Smelting and Refining Company (ASARCO), whose network of custom-built smelters to process diverse kinds of ores throughout Mexico did much to rejuvenate the whole Mexican mining industry. The stage was set for rapid developments in Durango and other Mexican districts.

In 1865, some of the Mapimí district mines were purchased from local owners by one A. B. Sawyer, who sold them, some years later, to the Durango-Mapimí Mining Company, incorporated in Council Bluffs, Iowa. This firm, many of whose stockholders were rich men of Durango, spent more than $100,000 on infrastructure, consolidated eight district mines (the Ojuela, San Vicente, Socavon, Santa Rita, El Carmen, Santa Maria, Soledad and San Judas), and smelted upwards of 20 tons of ore a day for several years. Dahlgren (1883) reports that the Mapimí district was then "the seat of a heavy smelting operation," processing ore from a group of district mines. The Ojuela, at the time only 768 feet deep, is listed with the rest and in no particular way distinguished from them. In fact, Dahlgren's 1883 list of Mexico's "best mines from past history," lists for Durango State the San Dimas, Topia, Guanacevi and Gabilanes mines, without even mentioning the Ojuela.

After the mid-1880's, when the Durango-Mapimí Mining Company went bankrupt and disbanded (Southworth, 1905; Bernstein, 1964), a new company, not part of the Guggenheim cartel, began operations in the Mapimí district. This Compañía Minera de Peñoles, backed by U.S., British and German capital, had already been working a silver mine about 60 kilometers west of Mapimí (Rice, 1908a). After complex negotiations with diverse local proprietors and with the old Durango-Mapimí Company, Peñoles purchased the Ojuela mine, which it called the "crown jewel" of the district (Campos *et al.*, 1988). On August 6, 1891, Peñoles Company officer C. Manuel Loyal Fernandez announced the successfully completed purchase in the company newsletter (Campos *et al.*, 1988).

Although the details of the early capitalistic arrangements which created the Peñoles Company remain a bit unclear in the available literature, a rough account can be reconstructed as follows:

The company was seeded with monies furnished by José Maria Bermejillo, "a Spanish capitalist of Mexico" (Bernstein, 1964), who employed an American mining engineer, Charles Reidt, to modernize the equipment and resume large-scale mining at Mapimí. The effort resulted in the discovery of "one of the greatest mining bonanzas in the Republic of Mexico" (Southworth, 1905), and the new company was promoted heavily in the United States. One of the promoters, who was buying ores in Mexico at the time, was Jacob Langeloth of Frankfurt-am-Main, through whom the fledgling Peñoles Company became in some manner "closely connected" (Bernstein, 1964) with Langeloth's own American Metal Company. That organization, founded in June of 1887, was controlled by Henry R. Merton & Company, London; Ladenburg, Thalmann & Company, New York; and Metallgesellschaft, Frankfurt, Germany. The Merton organization had originated in Frankfurt in 1824, when the banker Philip Abraham Cohen established an agency there to sell ores in Germany; Ralph Merton married Cohen's daughter, and their son Henry opened a branch of the Merton Group in London. Ladenburg, Thalmann was the Merton Group branch established in New York around 1880; this group had sent a Mr. Palmer Budd to Mexico to investigate possibilities for exporting metals. Jacob Langeloth, a member of the board of directors of Metallgesellschaft, negotiated the connection between the new Peñoles Company and the Merton Group, with the encouragement of Chairman Wilhelm Merton; another member of the same constellation was a company founded in 1890 in Mexico by Langeloth, the Compañia de Minerales y Metales, S.A., controlled, as was the American Metals Company, by the triumvirate of Merton, Ladenburg-Thalmann, and Metallgesellschaft. However murky the details of these arrangements might be, it is clear that the Peñoles Company before the first World War was truly a multinational corporation, with 49% of its capital investment coming from Germany. Officially organized on March 1, 1887, the Compañía Minera de Peñoles by 1903 had grown to become the largest independent base-metal enterprise in Mexico (Bernstein, 1964), and a worthy rival to the ASARCO empire of the Guggenheims.

The 24 years between the consolidation of the Peñoles Company and the fall of Diaz (1911) were the great glory days of mining at Mapimí. The company began by building an ore-smelting facility 6 kilometers from the Ojuela mine—at what had long been called the Hacienda de Agua ("House of Water"), near the hallowed old spring around which the town of Mapimí had grown up. A primitive plant of Castilian furnaces had been functioning marginally at the site since 1862, but the new smelter was an ultramodern facility, consisting of six water-jacketed furnaces with a daily capacity of 150 tons each. To connect the mine with the Mapimí smelter and the smelter with the outside world, a 24-kilometer stretch of railroad was built, terminating at the Bermejillo station of the Mexican Central Railroad system; with that system from the beginning there was an "arrangement whereby the Peñoles company [operated] its own trains over the tracks of the National Railways, [having] its own locomotives and other rolling stock, and [was] therefore not dependent for cars on the railroad company" (Parsons, 1925). Meanwhile the famous Roebling Bridge (see later) was built to connect the miners' village of Ojuela with the #4 shaft on the other side of the canyon. A 2-mile stretch of cog railway was constructed to negotiate a declivity of 1100 feet between this high-altitude complex and other facilities and mine openings in the valley, including the America Dos shaft, used for many years as a primary

Figure 13. **Ojuela miners' village ca. 1895-1910. Photo courtesy of the Mapimí mining museum and Brad van Scriver.**

REPÚBLICA MEXICANA.

COMPAÑÍA EXPLORADORA DE PEÑOLES S.A.

PEÑOLES EXPLORATION COMPANY S.A.

TÍTULO NÚM. 971

ACCIÓN NÚM. 971

VALOR DE CADA ACCIÓN $100

El portador representa en la Compañía Exploradora de Peñoles S.A. una acción de CIEN PESOS, totalmente pagada de las siete mil en que está dividida la negociación, con los derechos y obligaciones que expresan la Escritura social de seis de Febrero de mil novecientos doce, otorgada en esta Capital, ante el Notario Ignacio Alfaro y los Estatutos protocolizados en la misma fecha, ante el indicado Notario.

México, D.F. 1º de Julio de 1912.

MIEMBRO DEL CONSEJO

MIEMBRO DEL CONSEJO

10 CENT

AMERICAN BANK NOTE CO. NEW YORK. LITHO.

Figure 14. **Peñoles Company stock certificate dated 1912. Courtesy of Peter Megaw.**

Figure 15. **Over 4,000 50-kg Ojuela mine silver bars totaling about 7 million ounces, awaiting shipment from the depot in Bermejillo, ca. 1895-1910. Photo courtesy of the Mapimí mining museum.**

ore outlet for the mine's lower workings. The headframe of this famous shaft still stands as a prominent landmark today.

The whole operation was conceived in precisely the grand and progressive style envisioned by Diaz for contemporary Mexican industry. The Mapimí smelter facility offered comfortable housing for employees (with electric lighting!), and there were ample warehouses for the ore at the railroad terminus, and telephone lines linking train stations, smelter, and mine. The miners themselves were comfortably set up in a self-contained miners' village at Ojuela (see later).

In just a few years the Peñoles Company had converted a nest of insignificant, local ore-scratching activities at the Ojuela deposit into a massive, efficient system encompassing the whole Mapimí district: in 1893 only 32 mines in the region had been in operation, annually producing metals valued at $672,977, but by 1899, 218 mines were yielding metal values of $4,037,866 (Villarello, 1906). Most of these "mines" were later incorporated into the greater Ojuela mine, a patchwork of claims and workings centered around the America Dos shaft, the cog railway, the miners' village, the suspension bridge and the #4 shaft complex.

The railroad linking Mapimí to the station at Bermejillo was expertly managed by the engineer Charles Reidt (Southworth, 1905), and the cog railway made possible the transport of large machinery to the upland mine workings. But certainly the most dramatic element of the central complex was the suspension bridge which, at the time of its construction, was the second longest such span in the world. It connected the miners' village with the #4 shaft. Company literature credits the bridge to a "German engineer, Santiago Minguin" (Campos *et al*., 1988), but the contracting firm was that of John A. Roebling, New York. Mineral-collecting historians will recall that it was John A. Roebling's son Washington Roebling who, after distinguishing himself as a Union Army colonel during the Civil War, went on to build one of the greatest private mineral collections ever assembled in the United States, and to build the Brooklyn Bridge (see Roe, 1990). Although differing radically from the Brooklyn Bridge in the needs and the neighborhood that it served, the Ojuela bridge nevertheless instantly became "one of Mexico's man-made wonders" (Bancroft, 1984). It is 325.83 meters long and 1.83 meters wide, and is suspended 80 meters above the arroyo floor by six main steel cables each 5 cm in diameter. Hoffmann reported in 1967 that, although its wooden planking was in disrepair, the bridge remained structurally sound; Bancroft in the 1980's found it "charming and secure." For its 100th anniversary in 1991 the bridge was fully restored to serve as a tourist attraction.

The miners' village, constructed from scratch by the Peñoles Company, was, in its time, as much a triumph of modernity as was the Roebling bridge. Around 1905, about 5,000 people lived in the town, in houses furnished rent-free both to single miners and to those with families. The company provided the town with water from the spring at Mapimí via a complex system of pipes and a 200-horsepower pump; free public baths with both hot and cold water were available in the town (Southworth, 1905; Rice, 1908b). Among other amenities provided were a schoolhouse with two teachers, a full range of stores, a billiard hall, and a modern theater in which traveling acting companies performed; Bancroft (1984) mentions brothels as well, but it is unclear whether these too came courtesy of the company. There was a company doctor resident full-time in Ojuela, and there was a company hospital in Mapimí, with professional medical staff and modern surgical facilities. Moreover, the miners were paid far above average miners' wages then prevalent in Mexico, and the men could claim as much of their pay each day, including advances, as they desired. No wonder that even during these boom times, when other mines were chronically

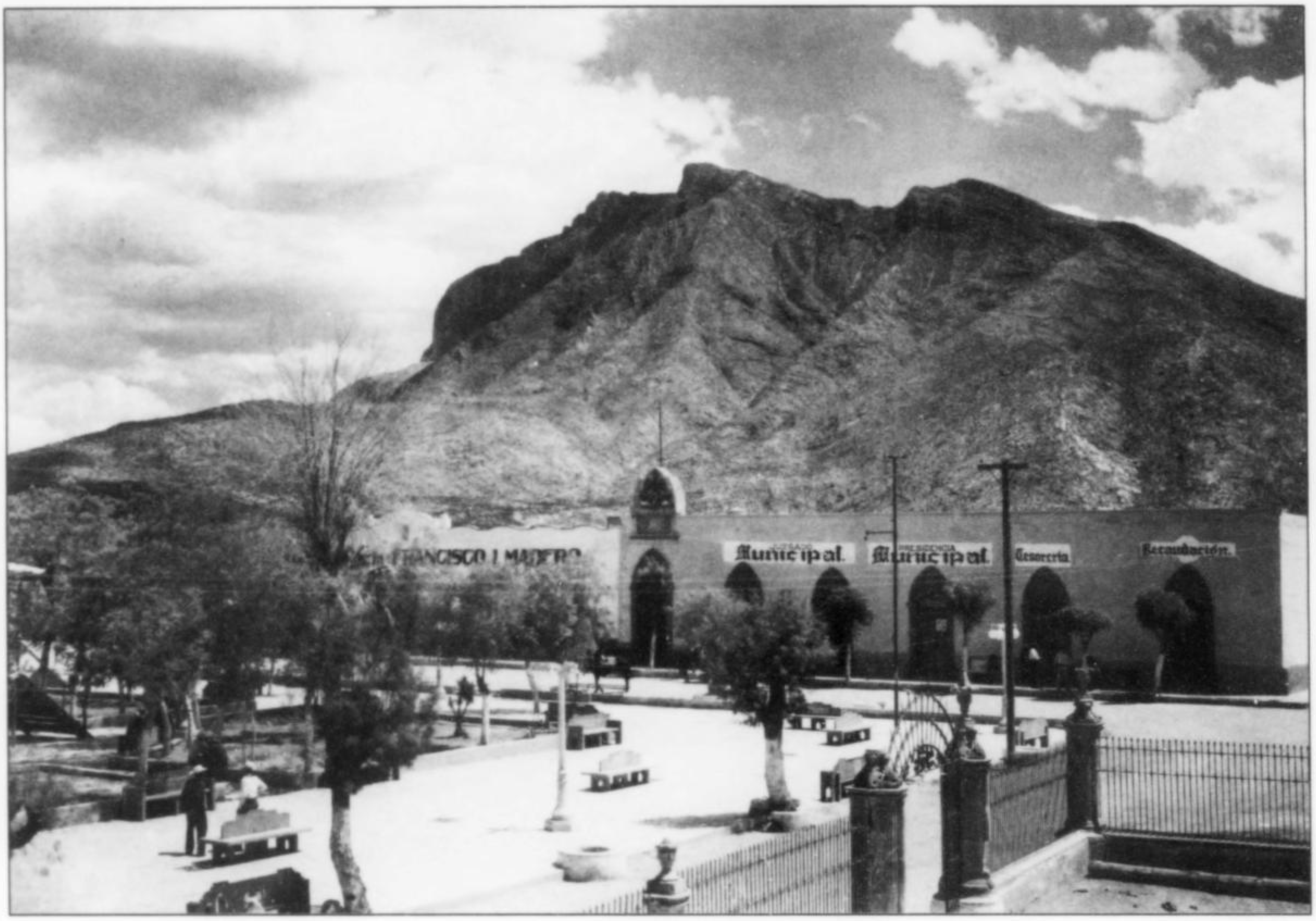


Figure 16. **The Mapimí town plaza, ca. 1895-1910. Photo courtesy of the Mapimí mining museum.**

short-handed, "the Peñoles Company had no trouble in getting all the miners that it desired" (Rice, 1908b).

Mining technology, too, was modernized during the 1890's. A large new steam generating plant was built to power the hoists and pumps, to light the mine workings, and to run the diamond drills used in prospecting for new veins (Southworth, 1905). A facility was constructed to process arsenic from the highly arsenical ores, achieving an average production of 1500 tons of refined white arsenic per year (Bernstein, 1964). A second remarkable suspension bridge, this one 60 feet long, was built *underground*, using old hoisting cable, in order to bridge an old stope so the ground on the other side could be prospected (Rice, 1908b). A new, sophisticated system for prospecting by taking corings along the drifts with the diamond drills was also devised (Rice, 1908b).

As the regime of Diaz neared its end, about 1200 miners were at work underground in the Ojuela mine, and 500 tons of ore a day (the great bulk of it oxide, a small part sulfide) were being produced (Rice, 1908a). The average annual net yield was two million dollars, and shareholders earned monthly dividends of forty dollars per share (Southworth, 1905). At the same time, other companies were winning large profits from many other mines in Durango, often smelting their ores in the Peñoles smelter at Mapimí and paying Peñoles well for the privilege (Villarello, 1909). Contemporary accounts from the years 1900–1910 ring with good cheer, optimism and satisfaction.

1910–ca. 1945

When President Porfirio Diaz attempted to run for still another term in 1911, he found that enough resentment against him had accumulated to start a revolution. Of course, patriotic and economic resentments reinforced each other: the feeling that Diaz "had literally sold Mexico off to foreign capitalists" (Bariand *et al.*, 1998) echoed emotions of a century earlier, when three centuries of foreign (Spanish) exploitation had finally sparked the wars for independence. Diaz had saved Mexico from backwater status among nations, but his economic policies, of which the most important were mining policies, had so favored large foreign enterprise over small Mexican enterprise that by the end of 1912, only $15 million of investment in mining out of a total of about $323 million was purely Mexican (Jenison, 1923b).

Between 1911 and 1920, as federal presidents came and went (two "went" by assassination), confused civil warfare returned to the countryside, to the detriment of such inherently peace-loving enterprises as the metal mines. Further echoing what had happened a century earlier, "general lawlessness prevailed. . . . Raids, 'confiscation' of supplies, ore and concentrates, and bullion, levying of tribute, and the kidnapping and murder of employees by bandits and guerillas became commonplace" (Jenison, 1923b). Even while these conditions were seriously curtailing production at many mines, the government of President Venestiano Carranza massively increased taxes, with the idea of breaking up some of the large foreign holdings, preventing further speculation, and discouraging the foreigners' exploration for new deposits (Jenison, 1923b; Waszkis, 1993).

World War I provided something of a boost for the mines, as it caused metal values to rise, but the silver mines suffered from the reduction in imports of German cyanide, and all mines suffered from the U.S. embargo on dynamite shipments to Mexico, whose government was pro-German (Bariand *et al.*, 1998). By 1919, only about 12% of all Mexican metal mines, and 21% of Mexican smelters, were still in operation (Waszkis, 1993). The Constitution of 1917 proclaimed the principle that the Mexican nation owned all natural resources in Mexico. In 1924, President Plutarco Elias Calles interpreted the controversial Article 27 of the Constitution to mean that the government could expropriate (seize) any foreign concession it held to be undesirable (Bariand *et al.*, 1998)—so much for Diaz' guarantee that foreign investors would be considered to own their Mexican interests "in perpetuity." In reality, though, almost no foreign interests suffered expropriation, and the Peñoles Company seemed particularly safe, since during World War I, to placate its British and American interests, it had restructured itself to eliminate the German interests; the Compañia de Minerales y Metales had done the same, and in 1920 it merged with Peñoles. By the early 1920's Peñoles, from its many mining involvements, was providing about a third of Mexico's total lead production and a fourth of its silver production (Parsons, 1925), so it was too important to be threatened by the general mood of socialism, populism, and xenophobia—the complex of feelings symbolized well by the famous figures of the times' two eminent bandits/freedom fighters, Pancho Villa and Emiliano Zapata.

New tax laws in 1918, a return of civil order, and some easing of the restrictions on foreign investors, helped Mexican mining revive considerably during the 1920's. Exploitation of complex polymetallic ores like those of the Mapimí district was greatly furthered, too, by the maturation of the selective flotation process in the 1920's: fine particles of different metals, clinging to different oils and chemicals when mixed with air and water, could be recovered separately. Thanks to the invention of galvanization and the resultant surge in demand for zinc, Mexican zinc production rose from 1200 tons in 1921 to 175,000 tons in 1929; lead production rose from 45,000 tons in 1917 to 175,000 tons in 1929 (Waszkis, 1993). Although no new major deposits were found during this time, Mexico in the 1920's became the second largest lead-producing country in the world, and one of the largest zinc producers (Waszkis, 1993).

A 1925 article by an editor of the *Engineering and Mining Journal* (Parsons, 1925) passes on optimistic reports by Heath Steele, then president of the Peñoles Company, about "expanded operations" and new plans for Peñoles in Mexico. The company is referred to as "the Mexican subsidiary of The American Metal Company," and one wonders whether American Metal had also severed its former German ties; the habit of leaving the company's real structure and ownership somewhat vague seems to have persisted. Suspiciously, according to a much later source, non-Mexicans still controlled 95% of all Mexican mining operations in 1926, despite the attempted reforms of the revolution (Waszkis, 1993).

The 1925 report describes the company's "plans for extensive underground development at several of its properties . . . and further important additions to plant and equipment, looking to increased production and more economical operation" (Parsons, 1925). Smelting operations were now being transferred from the old near-site plant in Mapimí, closed in 1919 (and from two other older plants, at Villaldama and Cerralvo), to two new, much larger smelters, at Torreon and Monterrey. The latter smelter was one of Mexico's only two lead-refining facilities, with the capacity to produce 7,000 tons of lead bullion per month. The executive offices of the Peñoles Company were also then in Monterrey. The Torreon smelter was also used during this time for preliminary recovery of arsenic from the Mapimí ores, the concentrate being sent back to the older arsenic plant in Mapimí to be refined and barreled for shipment.

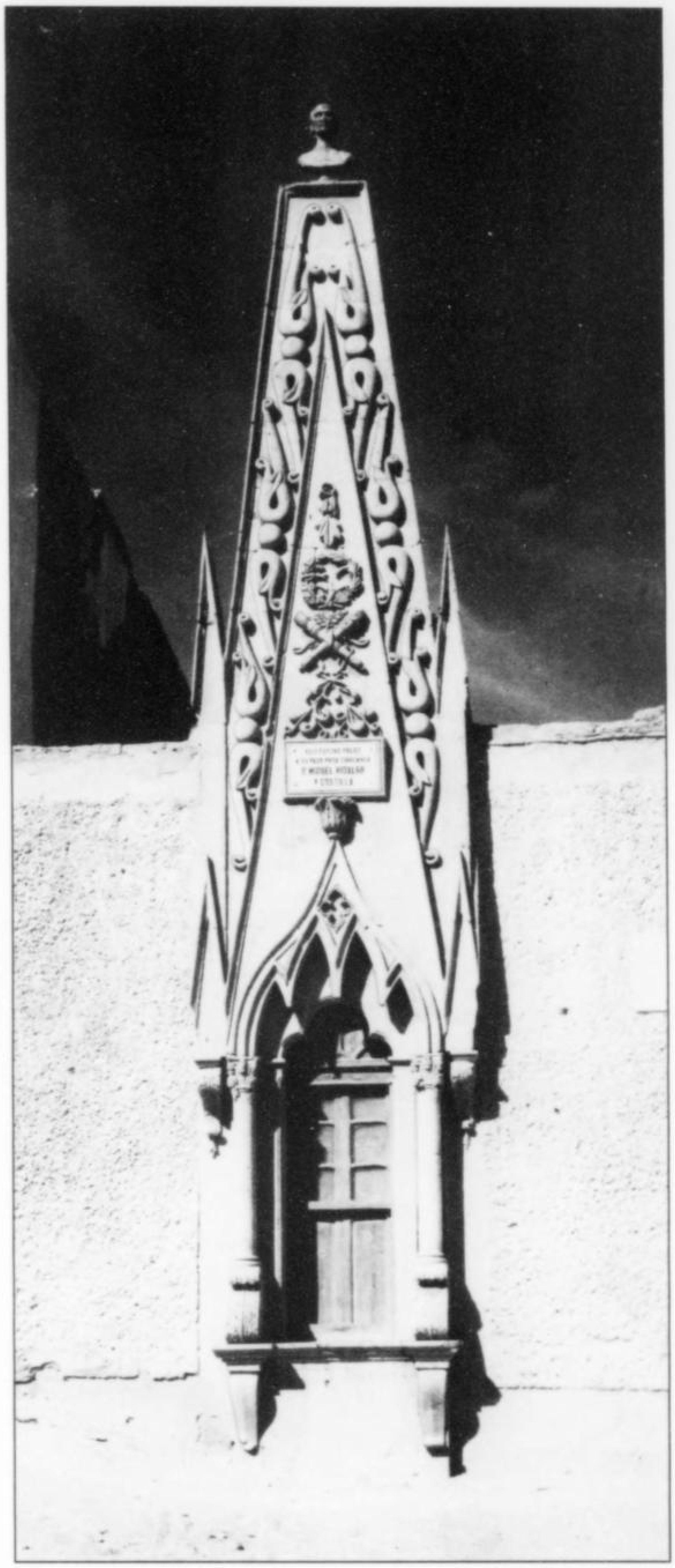


Figure 17. **Commemorative spire in Mapimí marking the entrance to a building in which Don Miguel Hidalgo y Costilla, revered as the Father of Mexican Independence, was imprisoned while on his way to Chihuahua City to be executed in 1811.**

Exploratory drilling in the Ojuela mine (there are today some 800 kilometers of exploratory drill holes) was in high gear during the 1920's, and drill cores from 850 meters below the water table at the mine's "bottom" revealed rich sulfide ores, primarily arsenopyrite, at depth. A new, much more powerful pumping plant was

Figure 18. **Bruce Thompson, one of the earliest American mineral collectors to visit the Ojuela mine, at the entrance to an adit (probably America Dos) in 1947. The mine mule is strapped with water barrels for the miners. Thompson and his brother "Slim" spent a week going underground, visiting the important *lugares* known at the time for adamite, wulfenite and other species. Photo courtesy of Bruce Thompson.**

installed during this time "to make possible development below the water level, where no work has been done heretofore" (Parsons, 1925). This innovation would prove to be of major significance for mineral collectors, since the great adamite and legrandite pockets which clustered around the water table at ca. 1,200 feet would come within reach once these first really serious pumps were emplaced in the mid-1920's.

The 1925 report concludes by affirming that "a period of real prosperity seems assured." However, Hoffmann (1967) writes that, as early as 1923–24, "the production of the mines began to decrease rapidly," and the glowing report has the sound, in retrospect, of company "spin." Metal prices in general declined during the 1920's, and fell very steeply during the world economic depression of the 1930's. In 1932, major flooding in the Ojuela mine's lower levels (despite the new pumps) paralyzed operations, and the problem of rising waters continued to plague the mine throughout the few years remaining to it. There were temporary upturns, as in 1934, when the U.S. Treasury bought huge amounts of silver and very briefly doubled the price of the metal, but the downward trend at the mine continued inexorably, and by the late 1930's production of ore in the Mapimí district had almost ceased (Hoffmann, 1967). The last small upward blip came during World War II, but very soon after the end of hostilities in 1945 the Ojuela mine switched to its present regime of being worked by local cooperatives of Mexican miners, by contract agreement with Peñoles. The era of large-scale industrial mining of ore was over; the era of local entrepreneurship, with a gradually increasing focus on specimen-mining, began.

1945–Present

The inauguration of President Lázaro Cárdenas in 1935 began a new phase of Mexican nationalism and economic-industrial protectionism. Cárdenas did not seek to close Mexico entirely to foreign investors, but so discouraged outside investment and expertise that, for example, a foreign engineer, in order to obtain a six-month work passport, had to prove that no Mexican was available for his job (Bernstein, 1964). One effect of the new protectionism was that it encouraged the growing movement toward forming producers' cooperatives in the mining industry, as these cooperatives seemed, in the government's view, to offer "the best way to free the Mexican miner from his dependence upon foreign capital and to develop in him a sense of managerial responsibility" (Bernstein, 1964). Although controversial from the start, cooperatives were organized throughout Mexico in the mid-1930's. As ores in the old mines ran out or became too lean to be profitably worked by the companies, the cooperatives were allowed to lease the mines and sell to the companies whatever ore they could dig. The miners who joined cooperatives would forfeit the severance pay they would otherwise get from the companies if the mines were shut down, but at least they remained employed in their trade. Of course, the system had many problems, especially when many cooperatives proved unable to sustain themselves and required massive government subsidies. Also, the cooperatives tended to prefer to work old, established mines (as in the Mapimí district), and found few new deposits, although a major original goal of the movement had been to set miners free to open and develop new or long-neglected mines. Furthermore, because they paid minimal taxes, the cooperatives narrowed the national tax base and thus deprived the federal and state governments of the very funds which the cooperatives themselves kept requiring as subsidies in order to keep functioning. Bernstein (1964) concludes that "despite some successes the development of cooperatives *per se* was not the hoped-for universal panacea" as ore grades declined and mining in general became relatively less important to the Mexican economy.

Although most of the early cooperatives were short-lived, the one which began in the late 1930's to negotiate its arrangements with the Peñoles Company at the Ojuela mine has proven amazingly durable. Through the 1980's it continued to work the deposit and to sell ore to Peñoles at the rate of 400–600 tons per month, and presently the cooperative miners search for mineral specimens (see below). In the early days, however, major problems arose when large numbers of free-lance miners (*buscones*), not affiliated with the cooperative and financed by illegal ore buyers, moved in and stole ore from remote parts of the workings. Peñoles dealt with the difficulty intelligently by rationalizing these illegal enterprises, authorizing the cooperative to organize an ore-buying agency to purchase the *buscones'* ore, and prevailing on the cooperative to take many of the *buscones* into membership. Even though some of the former free-lancers kept complaining that they were being cheated, the cooperative at the Ojuela continued to function well in extracting ore from a mine no longer workable profitably in the old industrial style.

The principle which prevails to this day is that, in exchange for the right to work the mine, the cooperative sells the ore to the Peñoles Company—although in 1991 the Company stopped buying ores which were too arsenic-rich, since processing such ores creates major environmental hazards. Over the years the number of active cooperative miners has fluctuated widely, at most reaching around 125. In the mid-1980's the figure was closer to 40; at the start of the new millennium it hovers around 10. All of these miners, some of them only teenagers, were and are native Mexicans, many of them from families whose men have been miners for generations. Beginning in the mid-1940's, Don Santos Pargas, the Peñoles Company's universally well-regarded representative, conducted business with the cooperative from his home in Mapimí. Despite his death in 1987, the relationship between the cooperative and the company has continued smoothly.

When, in 1946, an enormous grotto of crystallized adamite was discovered on Level 4 (see sidebar, "First Discovery of Adamite at the Ojuela mine"), the locality began to gain fame as a producer of wonderful mineral specimens, and business at the old mine underwent a sea-change. By formal agreement, miners who sold crystal specimens were to remit 10% of the sale price to the Peñoles Company; but, as at so many other famous localities, they soon learned that by smuggling specimens out and stashing them until buyers came, they could avoid the royalty while turning much more profit from their labor than by straight mining of ore. The inherent (familiar) conflict between ore-digging and crystal-collecting went unresolved until 1995.

The onset of the Ojuela mine's fame as a world-class mineral locality was due not only to the collecting efforts of the men of the *cooperative*, but also to those of outsiders, chief among them an American, George Griffith, who came, with his wife Katie, in the late 1940's to settle in the town of Gomez Palacio, about 25 km from Mapimi. Griffith formed a collecting partnership with two Mexicans, Manuel Lopez (a former Peñoles-affiliated *cooperativo*), and Enrique Loera, and this team had many great days in the Ojuela mine. Lopez today recalls how they worked in the tremendous adamite grotto of 1946, loading tons of specimens, as tons of ore had been loaded in earlier times, into sacks to be slung across burros' backs for transport down to the valley. The team collected beautiful deep blue aurichalcite (Lopez remembers one amazing plate 30 cm across) from the Cumbres *lugar* ("collecting area"), and hemimorphite crystal groups by the bucketful from a *lugar* called Maria, on Level 3. They found beautiful crystals of an unknown yellow mineral and gave them to California mineral dealer George Burnham to take to George Switzer at the Smithsonian, and soon thereafter the formal description of the new species paradamite appeared (Switzer, 1956). George Griffith's rock shop in Gomez Palacio, the "Casa de Las Rocas," became a mineralogical tourist mecca, as well as an informal training academy where Mexican miners were taught how to recognize and handle delicate specimens. Griffith contributed enormously to the fame of the Ojuela mine, and preserved many thousands of fine specimens which otherwise would probably have been lost. He died in 1989, but Katie Griffith today still presides at Casa de Las Rocas. Her private collection of Ojuela mine specimens is not on view, but visitors would still be well advised to browse in the spacious shop on its busy corner in downtown Gomez Palacio.

News of exciting discoveries of specimens quickly spread, and informal articles appeared in the collector literature about the specimen-paradise that was Mapimi (e.g. Johnson, 1962; Miller and Olson, 1970; Burton, 1976). More Americans came to dig in the Ojuela mine, including the famous dealer/collector Willard Perkin, who worked intermittently between 1959 and the early 1980's. In the mid-1960's, Victor Hoffmann came down from the University of Arizona to conduct research; his Ph.D. dissertation (Hoffmann, 1967), has been for all these years the best and virtually the only detailed account of the mineralogy of the deposit. In 1979–1980, Curt Van Scriver and John Whitmire worked in the mine, but since they only had tourist visas, they were eventually asked to leave by the Mexican immigration authorities (Whitmire returned to become a major player in the great purple adamite strike of 1981—see sidebar, "Purple Adamite Tales"). Pioneer collectors of these early decades often remember Mapimí as an intimidating place: C. Sheldon "Slim" Thompson (who visited the mine twice in 1947) and Victor Hoffmann in the 1960's were both accosted by bandito-like Mexicans with rifles or machetes, who tried to frighten them away or to confiscate their bags of mineral specimens (personal communications, 2003).

Meanwhile, local enterprisers caught the kind of mineral-commercial fever which can enliven life in otherwise sleepy places. In Bermejillo, particularly in the days before the toll road went in, between five and eight "rock shops" offered material from throughout the Mapimí district and from other places in Mexico (with, often, the result that specimens bought in those days were permanently misdesignated "Ojuela mine" or "Mapimí"). The few shops which survive today mostly sell things like Chihuahua sand selenite, Wyoming fossils and Brazilian agates (plus bits of low-end Ojuela mine material furnished to them by Mike New), but it was possible during the middle decades of the 20th century to find truly fine Ojuela mine specimens for sale in Bermejillo and Mapimí town, as well as to find fine Musquiz fluorite, Velardeña mimetite, and assorted Mexican specimens of other kinds. Inevitably, commerce here had a dark side too: the owner of one prominent Bermejillo shop (not in business today) was a regular fabricator of fakes, offering such things as 3-cm legrandite crystals protruding from nearly closed adamite pockets, and celestine crystals glued to almost any "matrix" that came to hand (Peter Megaw, personal communication, 2003).

At the old mine workings, the miners' village atop the escarpment had become a ghost town, the Peñoles cogwheel-train line was long gone, and the miners of the cooperative now reached America Dos and other mine entrances in trucks and cars. But

Figure 19. **Felix Esquivel and his wife in November 1977, holding some of the exceptionally large and fine legrandite crystals that he had just collected at the Plan de Ayala *lugar*. Photo courtesy of Felix Esquivel.**

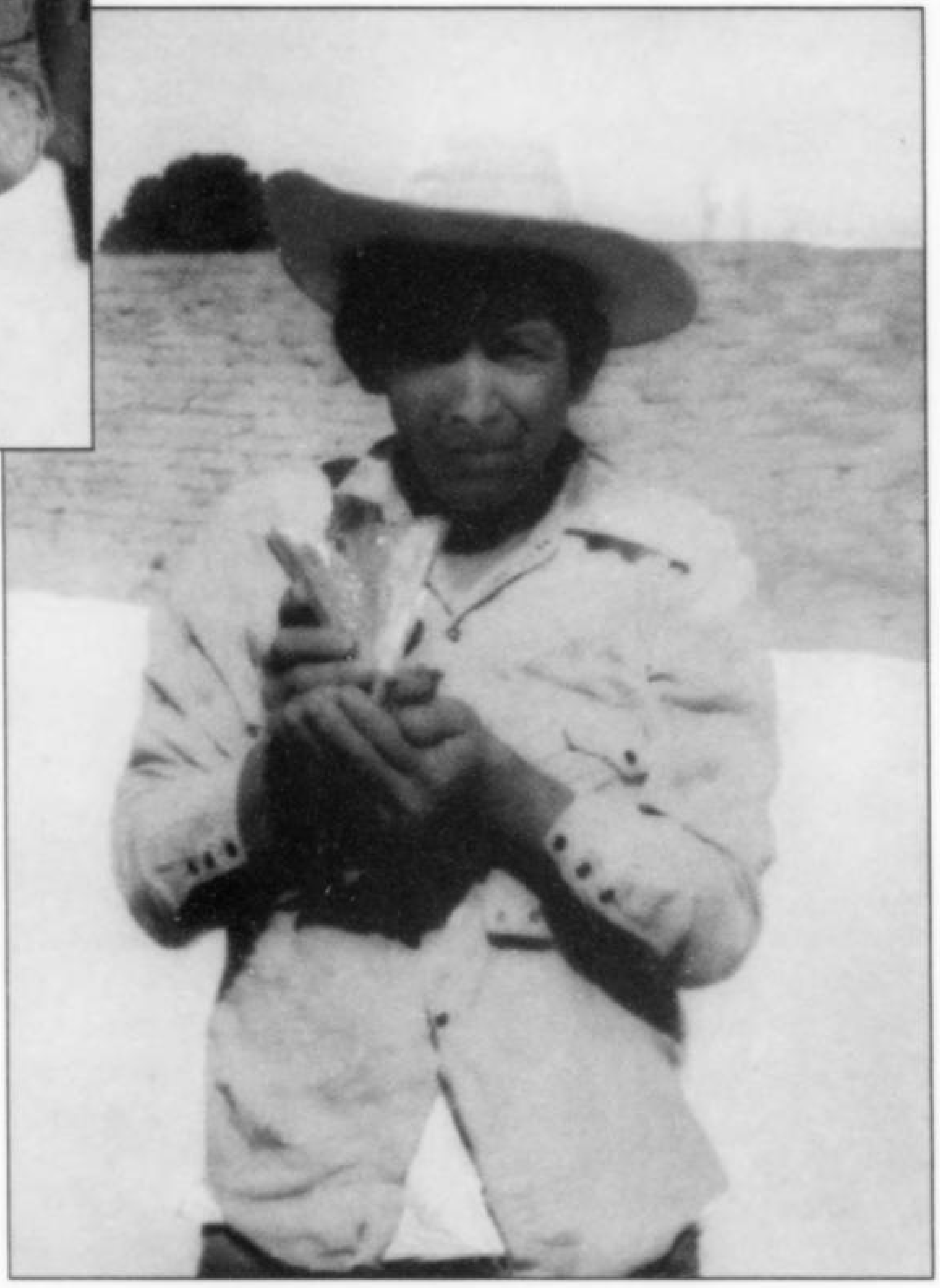


Figure 20. **Atenojenes Esquivel holding the "Aztec Sun" legrandite shortly after it was collected by his brother, Felix Esquivel, in November 1977. Photo courtesy of Felix Esquivel.**

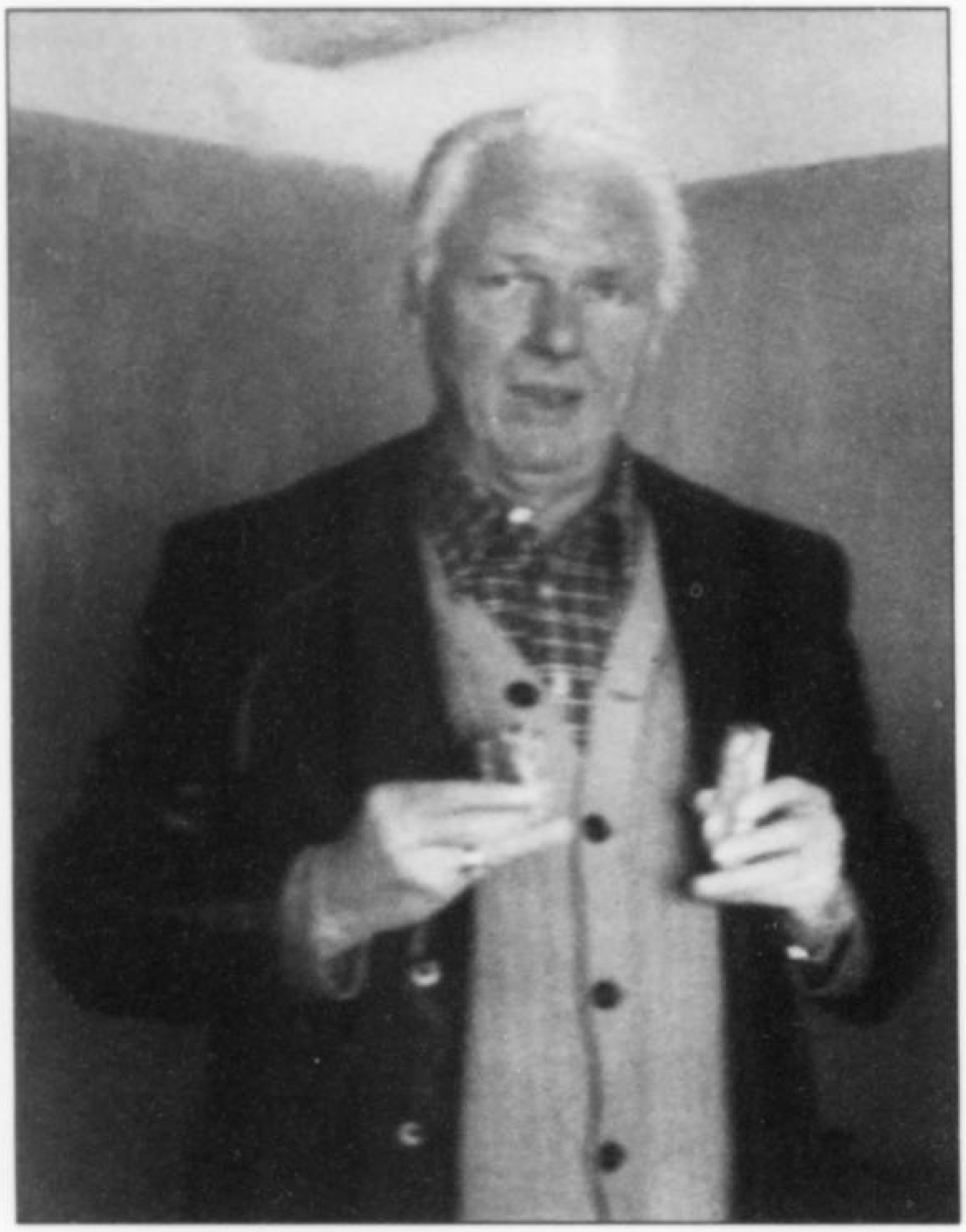


Figure 21. **El Paso mineral dealer Jack Amsbury in November 1977, holding legrandite crystals that had just been collected by Felix Esquivel. Photo courtesy of Felix Esquivel.**

some old methods persisted: once a year or so, ore-carrying mules would be brought into the mine, and would live the rest of their lives underground, wasting away from overwork or going blind, until new ones replaced them (Burton, 1976). The problem of disposing of these mules' manure was, as it were, subcontracted to thousands of large rats who lived in the mine, in a peaceful symbiosis with the mules and miners (see sidebar, "Purple Adamite Tales").

Politically, the persisting problem was that of the piratical *busceros*, now more frequently called *risceros* (from *riscos*, "treasure"; a *riscero* is a shady kind of treasure-seeker). The *risceros* "stole" both ore and specimens from the miners of the cooperative; some 50 of them were active around 1960, and confrontations, turf wars, and even violence were not uncommon in the workings. Don Lazaro de Anda Barraza, a major specimen-buyer during the 1960's, did business with cooperative miners and *risceros* alike; his son, of the same name, is the chief agent for *Top Gem Minerals*, the current holder of an overall collecting contract for the Ojuela mine.

Top Gem is a mineral wholesaling company run by Mike New, of Tucson, and Rubén Avila, of Ciudad Juarez. In 1995, by contract arrangement with Peñoles and with the miners' cooperative, the

Figure 22. **Katie Griffith (widow of American-born Mexican minerals dealer George Griffith) and George Griffith's partner from the 1940's, Manuel Lopez, holding specimens in the court-yard of Katie Griffith's home in Gomez Palacio, November 2002. T. Moore photo.**

partnership received the sole right to export and market specimens from the mine, employing the miners directly while paying percentages of profits both to the cooperative organization and to Peñoles. Top Gem has first right of refusal on any specimens the miners find and, in fact, buys and markets tons of material each year. The company has supervised much mucking-out in the mine, explores the mineralization intelligently, and treats the miners well, paying them a straight salary for routine maintenance work and empowering them to dicker on prices for any serious specimens found.

Before the days of the wholesale contract, Mike New and his miners were instrumental in developing the great strike of purple adamite in the San Judas chimney (see sidebar, "Purple Adamite Tales") in 1981, and in taking out great numbers of fine specimens of wulfenite on green mimetite which were found in 1968, and again in 1981, in a *lugar* on Level 5 (more of these are emerging as of this writing in spring 2003). In October of 2002, in a highly mineralized zone in the San Judas chimney on Level 7 (downdip from the purple adamite zone), the miners entered a promising-looking region of pockets harboring yellow adamite crystals, attractive clusters of colorless, lustrous acicular crystals of aragonite, and hints of still more exciting items; the aragonite specimens, unlike anything ever found in the mine before, hit the mineral market at the end of 2002.

Nor is commercial ore-mining necessarily finished. Peñoles may someday resume mining in a huge, untapped body of oxidized zinc ore in one part of the mine—and more fine crystallized specimens may then appear. Although the Top Gem partners can sometimes be heard to complain that it has been a good many years since any really dramatic strikes of first-class specimens have been made, the promising recent developments (just mentioned) show that the Ojuela mine remains capable of producing surprises at any time: this great locality cannot be considered finished.

Meanwhile, as with any great locality, there are the memories, stories and legends for us fans in the stands to live on; I will conclude this section with one such Ojuela mine story, from the Legrandite Era of the late 1970's. The greatest of the legrandite pockets of the Ojuela mine was breached in November 1977, in a *lugar* called Plan de Ayala, just below Level 5 in the San Juan Poniente stope. The pocket was almost, but not quite, discovered by a member of the cooperative who was known by the nickname of *Nariz Grande* ("Big Nose"). After following yellow stringers all day, the exhausted and discouraged Nariz Grande decided to give up and leave work for the day when his shift ended. At that point Felix Esquivel, a *riscero*, immediately moved in and, on the third stroke of his hammer, broke into a pocket which proved to measure 30 x 45 cm and contained the largest legrandite crystals ever seen in the mine (and therefore in the world), before or since. Esquivel and a partner, Ernesto Abasto, worked feverishly for six hours to enlarge the opening. Eventually Esquivel was able to reach in far enough to extend his whole arm to the back of the pocket. The legrandite crystals had already detached from the walls, and so the partners pulled out, one by one, horizontally through the hole, about 25 magnificent legrandite single crystals and parallel clusters, with legrandite individuals to 20 cm long; the biggest and best of these specimens is the famous "Aztec Sun," which went to the Miguel Romero collection, now at the University of Arizona. After much negotiating, Esquivel sold the specimens to a former "runner" (messenger) named Shorty Bonilla, an agent of Texas mineral dealer Jack Amsbury—for a total price of $3900. The find was one of the peak experiences of Felix Esquivel's life. Throughout the years since then he has proudly displayed on the wall of his house in Mapimí four photographs (three of them reproduced here) of himself and others holding the great legrandites.

Geology

The Ojuela mine is the most important producer in the Mapimí mining district, which lies on the northwestern edge of the Mesa Central physiographic province (Raisz, 1964). The Mesa Central is that portion of north-central Mexico lying north of the Trans-Mexico Volcanic Belt, between the Sierra Madre Oriental and Sierra Madre Occidental; it includes portions of the states of Guanajuato, Queretaro, Hidalgo, San Luis Potosi, Aguascalientes, Zacatecas and Durango. The region is characterized by broad plains, with mean elevations above 1700 meters, punctuated by mountain ranges rising to over 3000 meters. Vegetation is dominated by sparse thorny plants and cacti at low elevations, giving way upwards to patchy scrub oak forest. The climate is warm, with an average temperature of 21.5° C (a range of 0 to 45° C), and a median precipitation of less than 100 cm per year. There is virtually no surface water available at any time, but groundwater is locally abundant.

The Mapimí mining district lies at the northwestern end of the Sierra de Mapimí, a northwest-trending range that runs for over 60 kilometers from south of Torreon to the eastern edge of the "Bolson de Mapimí," a broad desert plain at 2000 meters elevation which extends 160 km from Mapimí to the Chihuahua border. The Ojuela mine area lies between 2100 and 2300 meters elevation in a narrow valley between the "Bufa Grande de Mapimí," a 2700-meter-high, nearly vertical, north-facing escarpment, and the "Bufa Chica de Mapimí," a linear south-facing ridge about 2500 meters high.

The Mapimí district is a typical Mexican Carbonate Replacement Deposit (Prescott, 1926; Megaw *et al.*, 1988; Megaw, 1999). These deposits, which include major specimen-producing districts

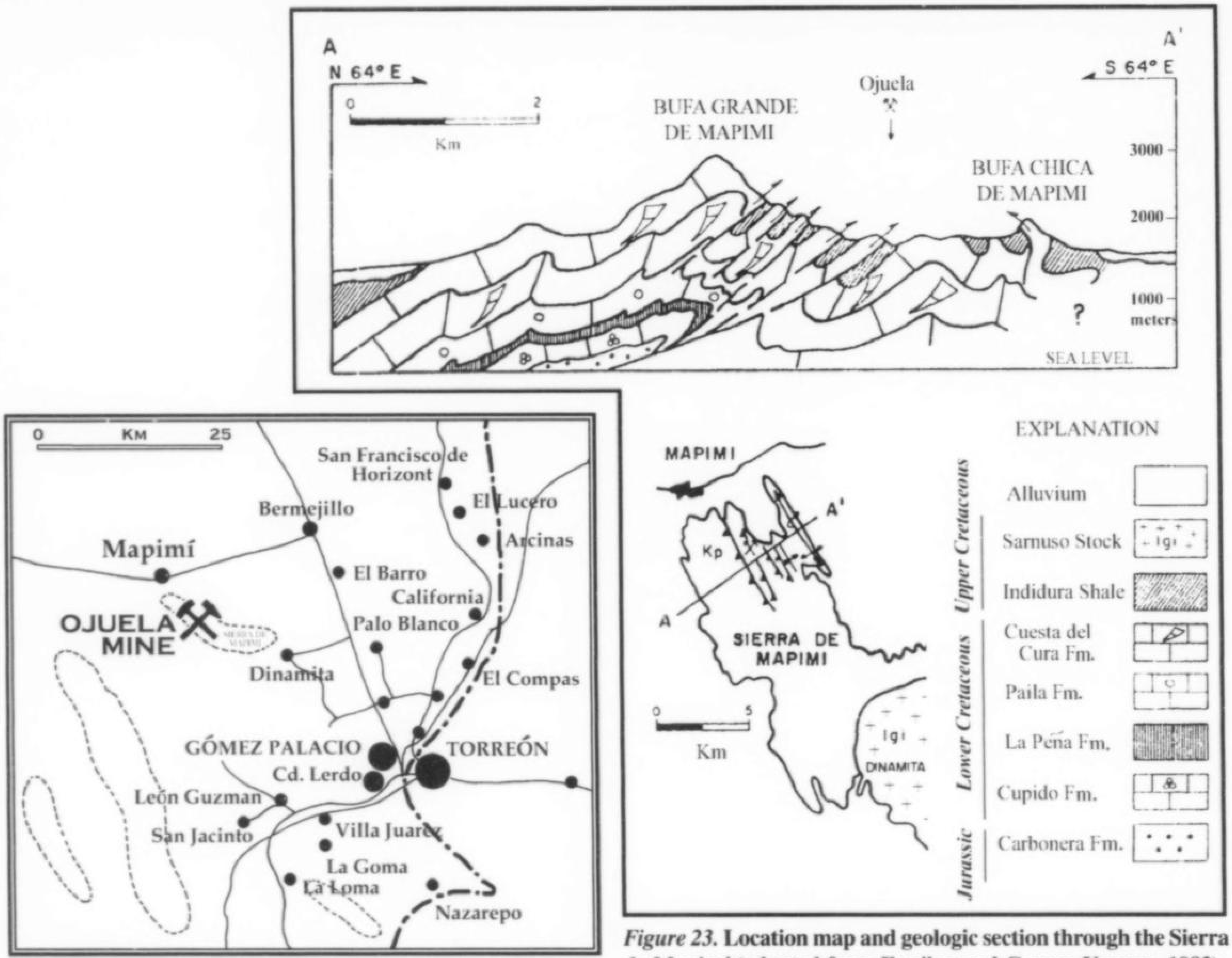


Figure 23. **Location map and geologic section through the Sierra de Mapimí (adapted from Equiluz and Campo-Uranga, 1982).**

such as Santa Eulalia, Naica, San Pedro Corralitos, Concepcion del Oro, Los Lamentos and Charcas, occur in a 2200-km-long belt of folded Mesozoic (150 to 65 Ma) carbonate rocks called the Mexican Fold Belt (Megaw *et al.*, 1988). The folding event created intricate structural plumbing systems that were followed by hydrothermal fluids generated during younger (45–25 Ma) magmatism.

Mineralization in these systems occurs predominantly by replacement, a process in which hot, acidic and saline ore fluids dissolve limestone or dolomite around the fractures along which they migrate, and the neutralization of the fluids causes almost immediate precipitation of sulfide or silicate minerals in the resulting micro-voids. The process often faithfully preserves delicate textures of the original rocks, including fossils and subtle bedding features. Replacement deposits form at depths of over a kilometer and are often found in direct contact with intrusive stocks, dikes, and sills: the deposits are commonly zoned from these intrusive bodies outwards. Calc-silicate skarns largely composed of garnet and pyroxenes accompanied by varying amounts of pyrite, pyrrhotite, galena, sphalerite, chalcopyrite, arsenopyrite and silver sulfides or sulfosalts occur along and near the intrusive contacts. These give way in outer zones to pod-like and elongate bodies composed almost exclusively of these same sulfides. Massive sulfide orebodies may extend for kilometers from the intrusive rocks. The orebodies are called "mantos" (Spanish for "blanket" or "mantle") when roughly horizontal and conformable with sedimentary bedding, or "chimneys" when steeply inclined and cutting across bedding.

Throughout northern Mexico, relatively recent (<20 Ma) regional block faulting has uplifted many replacement deposits to levels where descending surface (meteoric) waters can attack the primary sulfide minerals and oxidize them to a wide variety of secondary minerals. A volume reduction of 20% or more occurs during this process, resulting in abundant, and often very large, open spaces into which these secondary minerals can freely grow. Crystals exceeding 20 cm in length are not uncommon in these areas. The Mapimí deposit is one of the world's best examples of an oxidized replacement deposit, and is the source of well over a hundred superbly crystallized secondary mineral species, several of which are unique to the district.

Regional Geologic Framework

In a regional geological perspective, Mapimí lies along the intersection of the Laramide-aged Mexican Thrust Belt (Campa-Uranga, 1985) and the Tertiary volcanic plateau of the Sierra Madre Occidental. Mapimí is one of many similar districts that lie along this intersection from Hidalgo to near the Chihuahua-U.S.A. border (Megaw *et al.*, 1988). Mapimí lies on the northwestern edge of the Sierra Madre Oriental Terrane, a tectonostratigraphic terrane underlain by Precambrian continental crust (Campa and Coney, 1983; Sedlock *et al.*, 1993; Megaw *et al.*, 1988; Megaw, 1999). Within this terrane, Mapimí lies on the southwestern margin of the Coahuila Platform, a northeast-trending, fault-bounded basement high between the Chihuahua Trough to the west and the Central Mexico Basin to the south and east (Singewald, 1936; DeCserna, 1989; Moran-Zenteno, 1994). These basins accumulated a se-

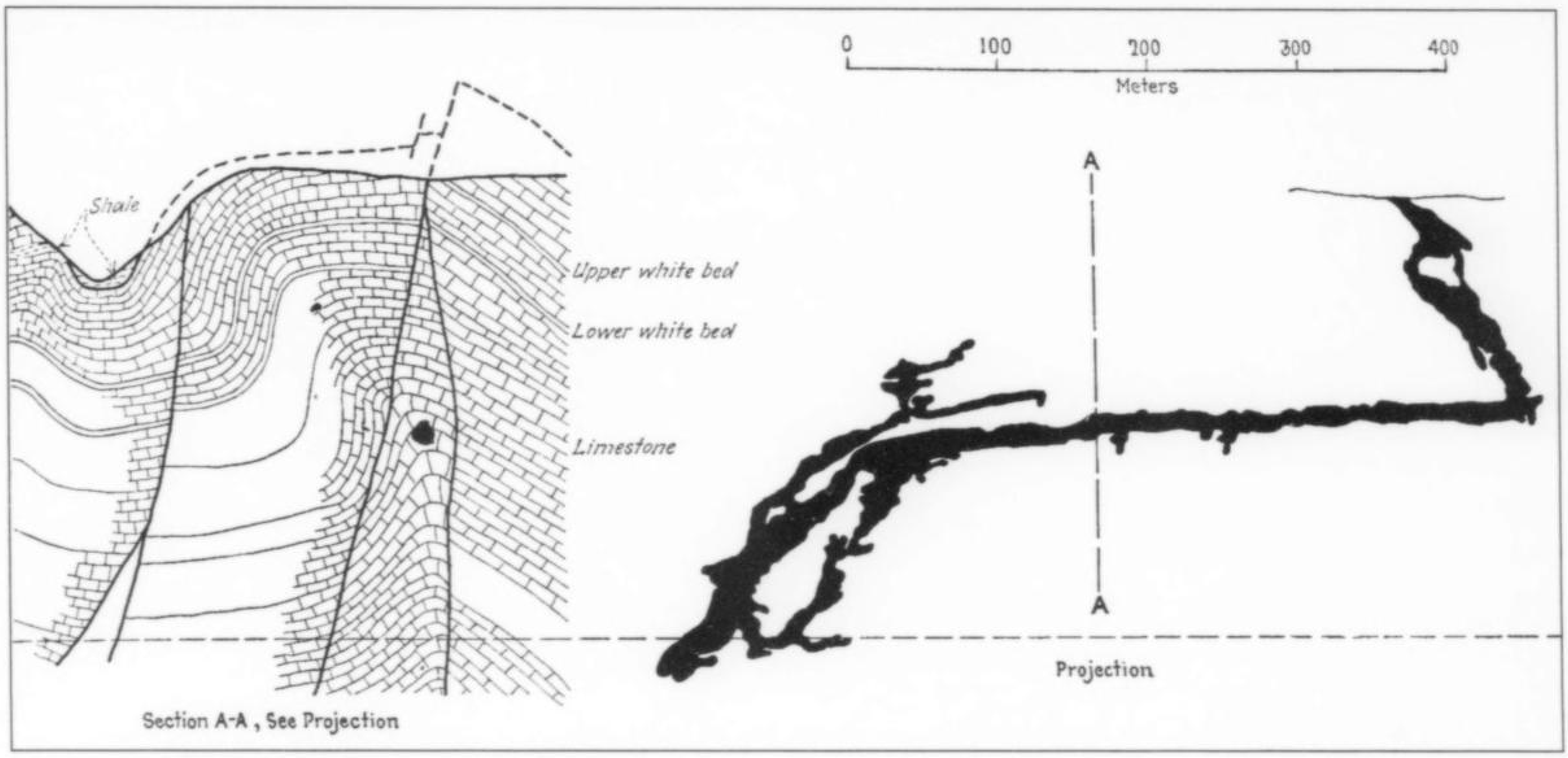


Figure 24. **Cross-sections through the San Jorge-San Juan orebodies, Ojuela mine (from Prescott, 1926).**

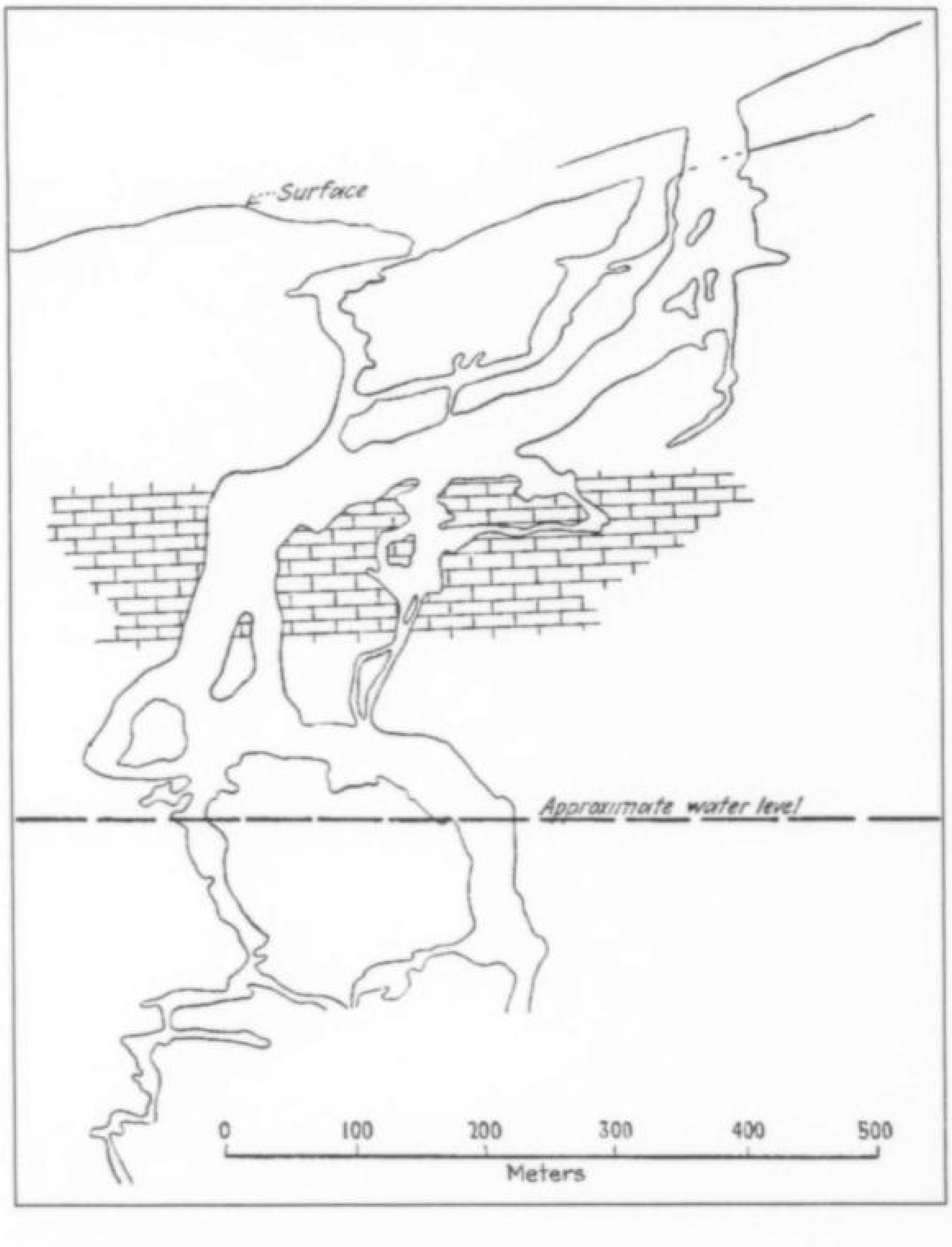


Figure 25. **Cross-section through the Ojuela-Paloma orebody, Ojuela mine (from Prescott, 1926)**

quence of redbeds, evaporites, and shale overlain by a thick sequence of limestones during the Jurassic through mid-Cretaceous. During this time, the Coahuila Platform was progressively drowned, changing from a peninsula to an island. Ultimately, by the mid-Cretaceous, it was completely covered by a shallow sea. Reefs developed along the outer slope of the Coahuila Platform where it dropped off into deeper water, and, as the water deepened, these reefs gradually migrated up the steep face of the platform. Reefal rocks are well developed in the Sierra de Mapimí, indicating that it lay right on the platform margin (Eguiluz, 1991). Hundreds of meters of carbonate were deposited on the platform until sea level dropped during the late Cretaceous and the carbonates were gradually covered by terrigenous sediments (shales and sandstones) which grew steadily coarser as deposition proceeded.

The Jurassic-Cretaceous sediments of the Central Mexico Basin and Coahuila Platform were subjected to strong southwest-northeast compression during the late Cretaceous-early Tertiary, as the North American and European Plates collided (Campa-Uranga, 1985). This event deformed the rocks into the generally northwest-trending folds and thrusts of the Mexican Fold-Thrust Belt (Sierra Madre Oriental) (Campa-Uranga, 1985). Deformation in many parts of the belt was thin-skinned, with detachment along the underlying incompetent evaporite units—what some geologists refer to as "rumpled carpet folding," in allusion to the rumpling of a loose carpet sliding over a slick hardwood floor.

An east-facing subduction zone was active along the west coast of Mexico at the same time that folding occurred. Subduction here generated an elongate magmatic arc, the ancestral Sierra Madre Occidental, marked at the surface by andesite stratavolcanoes (as in the current Cascade Range) and at depth by intrusions of comparable intermediate composition. Subduction continued until the mid-Tertiary, when the East Pacific Rise (the spreading center on the outboard side of the plate) was subducted (Atwater, 1970). As this happened, the crust began to relax and the style of volcanism shifted to voluminous silicic eruptions that created caldera complexes (as in the Yellowstone area). The southwest-northeast extensional relaxation reactivated ancient crustal faults, such as those bounding the Coahuila Platform, and many of these faults were invaded by intrusions that exploited these zones of weakness and rose to high levels in the crust. Many of these intrusions generated hydrothermal fluids that created replacement deposits where carbonate rocks overlay the faults (Megaw *et al.*, 1988; 1996). As the crust continued to relax through the mid to late Tertiary, the region became broken into elongate fault blocks roughly parallel to the elongate folds created during earlier compression (Megaw *et al.*, 1988; 1996). The combined structural history resulted in the northwest-elongate pattern of alternating fold ridges and alluvium-mantled valleys that characterizes the Mapimí region today.

Mapimí District Geology

The Sierra Mapimí is a very complex, north-plunging overturned anticlinorium trending N30–40°W, with multiple stacked thrust sheets of lower Cretaceous carbonates and shales. Amazingly, the stacking repeats the section at least six times, giving a greatly exaggerated thickness to the stratigraphic sequence.

The most important structure is a thrust fault that separates the Bufa Grande from the underlying fold that contains the bulk of the Ojuela mineralization. The lower plate of this thrust is a relatively open syncline-anticline pair with a backthrust that creates the Bufa Chica. The upper plate is an overturned tight fold with five thrust sheets that comprise the towering face of the Bufa Grande. The structures in both the upper and lower thrust plates are highly complex in detail. Eguiluz (1981) identified 12 major north-plunging recumbent folds in the upper plate, most of them overturned to the east, but some to the west. He further described 20 major open folds in the lower plate. The fold axes are cut by parallel, steeply dipping faults with up to 100 meters of normal displacement, giving the entire area a strong northwest-striking structural grain. Many of these faults acted as conduits for mineralization.

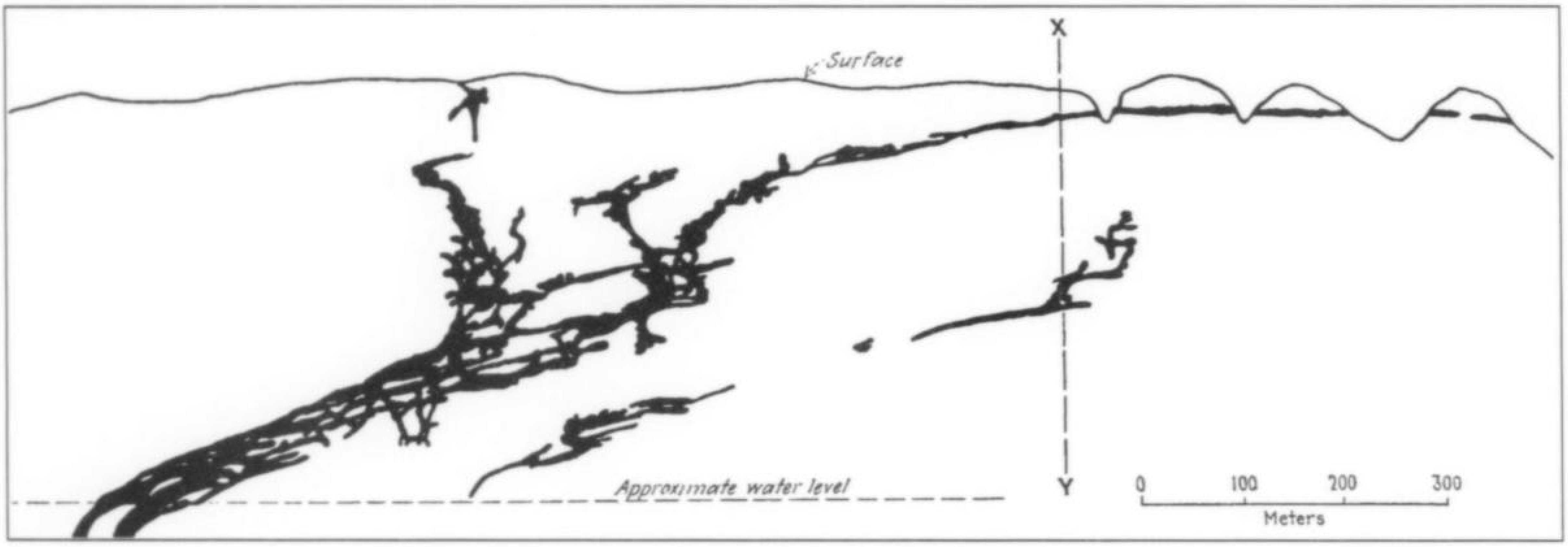


Figure 26. **Cross-section through the Cumbres orebody, Ojuela mine; projection N 32° W, looking northeast (from Prescott, 1926).**

The stratigraphic sequence is typical of the marginal part of the Central Mexico Basin. Calcareous shaly sandstones of the Upper Jurassic Carbonera Formation are the oldest rocks in the local section, but do not crop out in the immediate Mapimí area. These are overlain by Lower Cretaceous limestones of the Cupido Formation and shales of the La Peña Formation, which are widely exposed between Mapimí and the Sarnoso Stock. The next higher units are limestones, dolomitic limestones and dolostones of the Paila and Cuesta del Cura Formations. These are the most important host rocks for Mapimí mineralization (see below) and are widely exposed on the surface and underground. Many beds in the Cuesta del Cura contain abundant *Gryphea* (oyster) and *Caprinid* and *Toucasid* rudists typical of Lower Cretaceous reef environments. The youngest unit in the area is the Upper Cretaceous Indidura Shale, which hosts minor vein mineralization in the peripheries of the Mapimí system. Because many of the thrust faults slipped along these relatively incompetent shale beds, the Indidura crops out repeatedly as a series of linear bands in the thrust zones of the Bufa Grande and Bufa Chica.

Stratigraphic and structural information when taken together strongly indicates that the Sierra Mapimí lies on the margin of the Coahuila Platform, close to the deep basement fault that created the platform itself. This environment is comparable to that of other related Mexican deposits, including Santa Eulalia, Naica, San Martin and Velardeña, placing Mapimí centrally within the northwest-trending line of Mexico's largest carbonate replacement deposits (Megaw *et al.*, 1988; 1996; Barton *et al.*, 1995; Megaw, 1999).

Intrusive stocks, dikes, and sills ranging from intermediate to felsic in composition cut the district. The largest is the Sarnoso Stock, a 75-square-km body which is well exposed in an amphitheater-like valley in the center of the Sierra Mapimí Anticline at Dinamita, 12 km southeast of Mapimí. (The name Dinamita reflects the fact that DuPont built its first explosives plant in Mexico herein order to be close to Ojuela; it is still in operation nearly 70 years after Ojuela closed.) A satellite body of the same material 500 meters in diameter crops out at El Vergel, about 12 km farther west (Hoffmann, 1967). The Sarnoso Stock is composite, including five or six sequentially emplaced phases of varying composition. The earliest were hornblende diorite, followed by quartz diorite and monzonite zones and two late sodic granite pulses. The latest granites are cut by aplite, alaskite and carbonatite dikes and local simple quartz pegmatites (Salas, 1971; McLeroy *et al.*, 1986). The granitic phases range from equigranular to porphyritic and contain quartz, microcline, orthoclase, albite, biotite, hornblende and clinopyroxene phenocrysts with apatite, magnetite, zircon, titanite, and monazite accessory phases (Hoffmann, 1967). Carbonate was locally assimilated into the granite, creating nepheline syenite injected as dikes into the strongly silicified or silicated wallrocks (Salas, 1971).

A broad halo of metamorphic marble cut by metasomatic skarn surrounds the Sarnoso Stock. (This marble has been extensively quarried for tile and is featured in public buildings throughout Mexico.) The skarn affects both the intrusion (endoskarn) and surrounding carbonates (exoskarn); it includes andradite and grossular garnet, brucite, wollastonite, vesuvianite, spinel, phlogopite, zeolites and calcite. The stock margin is locally marked by marble breccias mineralized by magnetite and hematite and cut by later manganese-oxide veins (Salas, 1971; McLeroy *et al.*, 1986).

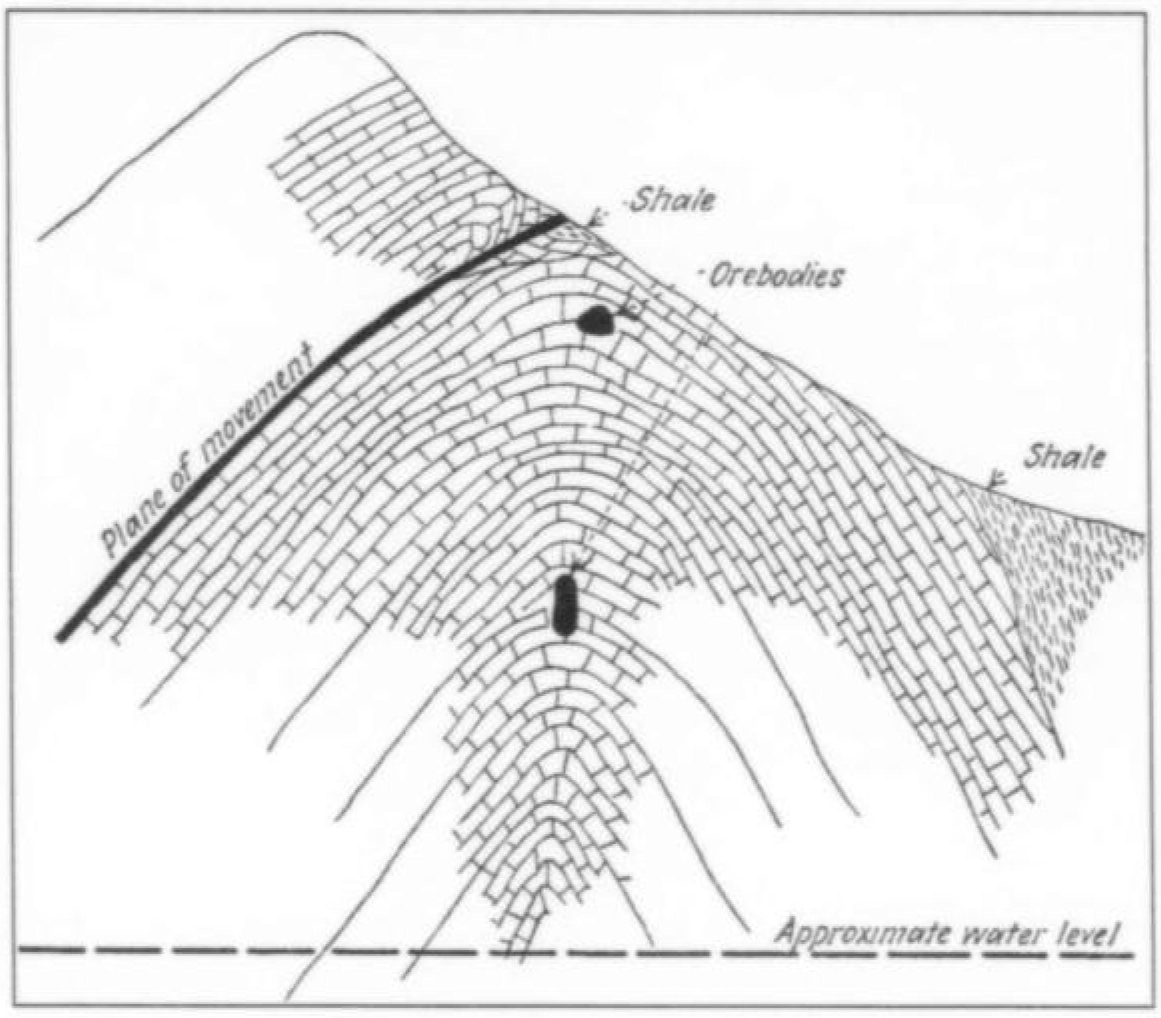


Figure 27. **Cross-section through the Cumbres orebody, Ojuela mine, through X-Y shown on Figure 26 (from Prescott, 1926).**

The 2-cubic-km Zacatera Diorite stock lies 9 km northwest of the Sarnoso Stock and about 2 km southeast of Ojuela. This is a composite, heterogeneous body with a light-colored phase rich in feldspars and a dark-colored phase rich in ferromagnesian minerals. Several small silver and antimony deposits occur near this stock (McLeroy *et al.*, 1986).

Fine-grained alaskite with associated skarn was reported by Spurr (1923) from core holes drilled 500 meters directly below the deepest levels of the mine. Spurr's description of the alaskite is incomplete, but McLeroy *et al.* (1986) suggested that this unit correlates with sparse outcrops of quartz latite that occur about 5 km northwest of Mapimí, in the Toboso Hills. Spurr also noted that the arsenopyrite content of mineralization increases significantly in the direction of the alaskite.

The mineralized area is cut by numerous fine to medium-grained diabase dikes. Many occur in the same structures that host mineralization, but only some are altered or mineralized.

Despite the close spatial and temporal proximity of the intrusions to mineralization, for various reasons many researchers (Singewald, 1936; Hoffmann, 1967; McLeroy *et al.*, 1976, 1986) have downplayed possible genetic links between most of the intrusive phases and the mineralization. However, the relationships seen between all the intrusive phases and the mineralization at Mapimí are strikingly similar to relationships seen in the Santa Eulalia, Concepcion del Oro, and San Martin-Sabinas districts, strongly indicating a genetic link between long-term magmatic differentiation and mineralization (Megaw, 1990; Barton *et al.*, 1995; Megaw *et al.*, 1998; Castro-Reino, in progress). If this link can be confirmed for Mapimí, it opens significant potential for finding additional mineralization centers in the district.

Mineralization

During the 334 years between 1598 and 1932, the Mapimí district produced a total of about six million tons of high-grade, silver-rich oxide ores and perhaps as much as a million tons of sulfides (Megaw *et al.*, 1988). Overall production grades were 15.0% Pb, 475 g/T (= 15 troy ounces) Ag, and 3.5 g/T (= 0.1 troy ounce) Au. Copper grading up to 3% was produced in limited areas (Campos *et al.*, 1988). Zinc is a prominent component of the ores, probably averaging 12–15%, but it was never recovered. The deep parts of the system contain potentially large sulfide resources, but their exploitation requires technology for eliminating the abundant arsenic. Peñoles retains ownership of the property because the company assumes that this will one day be possible.

Mineralization in the Mapimí district is typical of the larger Ag-Pb-Zn (Cu, Au) carbonate replacement deposits (CRDs) of Mexico (Megaw *et al.*, 1988, 1998). It shows a temporal and spatial relationship to a highly differentiated igneous system and is zoned on a scale of kilometers. On a district scale, mineralization grades from skarns developed along stock contacts, to skarns developed on the contacts of felsic dikes, to massive sulfide chimneys and mantos, to a complex but characteristic alteration envelope. On the scale of the Ojuela mine, mineralization grades from deep dike-contact skarns to massive sulfide bodies to replacement veins to late carbonate-stibnite veins, to distinctive manganese-silver carbonate impregnations. Zoning is also well developed within individual orebody types. The following discussion of Ojuela mine ores will begin with the deepest skarns and work upward and outward, as if the system were unoxidized. The oxidation of the system will be treated afterwards.

The deep contact skarns are only known from a series of 600–850-meter-deep holes drilled from the lowest levels of the mine (Spurr, 1923). Alaskite dikes encountered in this skarn zone are inferred to be closely related to mineralization. The skarns are typical of those affecting dolomitic limestone; they are composed of an anhydrous "prograde" suite including grossular-andradite, diopside, apatite, and wollastonite, with a hydrous "retrograde" overprint including tremolite, actinolite, vesuvianite, clinozoisite, pectolite, phlogopite, quartz and calcite (Meinert, 2002). The skarn is mineralized with pyrite, chalcopyrite, arsenopyrite, molybdenite, galena, sphalerite and enargite. Arsenopyrite can run as high as 20% of the total volume.

The massive sulfide orebodies of the Ojuela mine rose through the carbonate host rocks as seven major chimneys, which fed four groups of branching, complexly intersecting mantos (Villarello, 1906). The chimneys are developed along northwest-trending faults developed along fold axes, and the mantos commonly follow specific carbonate beds along the crests of these folds (Prescott, 1926). Sheet-like massive sulfide mantos are also developed in thin limestones sandwiched between shale beds in the lowermost part of the Indidura Shale. Prescott (1926) noted an overall zoning of metals, with the highest copper in the deepest zones, through a zone of zinc-lead, to lead-zinc-silver, to lead-silver. The primary sulfide ores in the copper-rich zone consist largely of sphalerite, chalcopyrite, pyrite and arsenopyrite, with lesser galena, molybdenite, enargite and marcasite (this may actually be pyrite pseudomorphing hexagonal pyrrhotite). The iron content of the sphalerite decreases upwards, as does the pervasiveness of "chalcopyrite disease" (chalcopyrite exsolution blebs within sphalerite) (McLeroy *et al.*, 1986). Sphalerite and galena are the dominant sulfides in the zinc-lead zone as chalcopyrite and enargite diminish upwards. The outer lead-silver zone is dominated by argentiferous galena, sphalerite, pyrite and arsenopyrite (now <1%), with minor chalcopyrite, molybdenite, enargite and stibnite. Varying amounts of calcite, dolomite, quartz and fluorite comprise the gangue throughout (McLeroy *et al.*, 1986).

The major chimneys include the San Vicente, San Ignacio (Monterrey), San Nicolas, San Judas, San Jorge-San Juan, San Antonio (Cumbres), and Ojuela (Palomas). The Ojuela chimney is the largest orebody in the mine. It stands over 1000 meters tall and has an elliptical plan of about 5000 square meters. This orebody produced 1,500,000 tonnes of ore grading 3 g/T Au, 500 g/T Ag, 10% Pb and 15% Zn. The zinc was not extracted, but remains on the walls of the stope as a shell of zinc oxide minerals.

Tabular replacement veins occur where fracture-controlled mineralization developed in relatively unreactive rocks, and lateral dissemination of ore was limited. Many of these veins occur along fold axes, and thus link chimneys and mantos developed higher and lower in the stratigraphic sequence. The Santa Rita vein is one of the largest of these: it yielded nearly 500,000 tons of ore grading 3 g/T Au, 500 g/T Ag, 10% Pb and 15% Zn.

The major mantos occur in clusters in the Ojuela, San Ignacio, Socavon, and Talpa (or Campo Sur) areas. Ojuela has several different styles of mantos ranging from elongate ribbons to sheet-like bodies. The Cumbres manto is over 1000 meters long and 10 x 25 meters in cross section. It lies immediately beneath a dolomitic bed along the crest of a fold. In contrast, the San Carlos manto is 50–100 cm thick, 200 meters wide and 500 meters on dip. It lies on the eastwardly-dipping east flank of a N35°W fold, and produced 250,000 tonnes of ore grading 200 g/T Ag and 8.5% Pb, with 11% Zn (not produced).

The mantos show remarkable lateral development in particular beds within the limestone-dolomitic limestone-dolostone sequence of the Cuesta del Cura Formation. The tendency of mineralization to develop well in one bed and hardly at all in adjacent beds above and below has long been referred to as "the favorable bed problem" (Prescott, 1916, 1926; Hayward and Triplett, 1931; Ohle, 1951; Megaw *et al.*, 1988; Megaw, 1990). Several tests of various hypotheses including chemical composition, fossil or organic content, and grain size were carried out at Ojuela (Prescott, 1926; Hayward and Triplett, 1931). In some places mineralization "mantos out" (blossoms laterally) in dolostones; in others it strictly follows dolomitic limestone; in still others it follows limestone beneath dolostone. The ultimate conclusion of these studies and related studies in other carbonate-hosted deposits is that chemical composition is inherently unimportant, but that for an ore fluid to pass through a carbonate rock, porosity and permeability must be enhanced by some secondary process. These processes can include fracturing (via faulting or folding), dissolution (via meteoric or hydrothermal karsting processes), heating, or dolomitization (Megaw *et al.*, 1988). Certain of these processes clearly affected different parts of the stratigraphy at Ojuela differently.

Much of the district's dolomite is depositional, but at least some appears to be secondary or hydrothermal in origin. There are significant textural differences between the two styles, and Foshag (1937) interpreted dolomitization as being zoned relative to mineralization. The limestone and dolomite rocks of the district are thermally recrystallized to coarse-grained marble around intrusion centers, and gradually diminish to sugary recrystallization outwards. Similar patterns have been noted around other carbonate replacement deposits in Mexico (Megaw and Titley, 1985).

Carbonate veins and veinlets lie outboard of many major orebodies. These are composed of calcite and manganoan siderite, with minor quartz, containing stibnite, pyrite and pyrargyrite. Commonly the vein minerals are weathered to stibiconite and mixed earthy oxides. Sulfide content in these veins diminishes outwards as they gradually become manganoan calcite veinlets, commonly outlined by dendritic argentiferous manganese-oxide mineralization (AMOM veinlets, Megaw, 1998). These veinlets mark the distal parts of the ore fluid pathways with fillings deposited from nearly spent ore fluids and late-stage fluids reflecting the collapse (or retreat) of the hydrothermal event (Rubin and Kyle, 1988; Megaw, 1998).

The Indidura shale is widely thermally metamorphosed to hornfels, a compact mixture of very fine-grained pyroxenes and garnets. This unit locally contains axinite as crystals to a few cm. No significant sulfide mineralization has been found in the Indidura shales beyond minor veinlets.

Oxidation

The composition of the primary sulfide ores directly influenced the composition of the secondary oxide minerals. Had the Ojuela ores consisted dominantly of pyrite, pyrrhotite, galena, sphalerite, and chalcopyrite, as is typical for most carbonate replacement deposits, we would probably revere the locality principally for the size of its crystals of "ordinary" secondary minerals. However, the high arsenopyrite content of the ores resulted in secondary ores rich in arsenates, rivaled only by Tsumeb (also an oxidized vertical sulfide chimney of mammoth proportions). The repetition of the process and the variability of chemical conditions caused by varying amounts of water and oxidation of different compositional zones of the primary mineralization resulted in the wide variety of exceptionally well crystallized supergene species.

Oxidation in the Ojuela mine extends to 700 meters below the surface (measured from the Tiro Norte collar), and encompasses all of the mantos and many of the chimneys. Oxidation is virtually total, but relict sulfides do survive locally. The suite of secondary oxide minerals for which Ojuela is justifiably famous is the product of the duration and nature of the oxidation process, the geometry of the Ojuela orebodies, and the composition of the primary sulfides.

Oxidation is a highly variable process strongly affected by the infiltration of meteoric waters; thus it is principally controlled by climate and rate of uplift. It is a very long-term process, so its advance is sporadic as wet and dry climatic cycles occur. The chemistry of the oxidizing fluids also varies depending on the amount of water passing through the system at any given time. Oxidation of pyrite, pyrrhotite and arsenopyrite in the primary sulfide ores creates a strongly acidic fluid that migrates away from the ore and reacts with the surrounding carbonates, creating cavernous voids into which supergene minerals can grow to large crystal sizes. The geometry and size of these voids is strongly influenced by the geometry of the orebodies. Flat-lying, relatively thin manto orebodies tend to develop relatively thin cavernous zones directly beneath the manto, whereas vertical chimneys tend to develop annular to cylindrical cavernous zones surrounding the chimney. Repeated flushing of oxidizing fluids through the chimney results in greater lateral cavern development at the base of the chimney than at the top; eventually an inverted carrot shape evolves.

The acidity of the oxidizing fluids also efficiently separates lead and zinc. Zinc is highly soluble and is readily leached from the oxidizing sulfides, leaving the relatively insoluble lead to be residually enriched, *in situ*, as argentiferous cerussite. The zinc remains in solution until the acid fluids are neutralized through reaction with the carbonate wallrocks (again increasing the amount of void space), and reprecipitates as supergene zinc minerals. At Ojuela, the combination of this oxidation-separation process with repeated flushing along the axes of the chimneys yielded a shell of supergene zinc mineralization surrounding cores of argentiferous cerussite.

Historic mining focused on the argentiferous cerussite, leaving the shell of supergene zinc mineralization behind. New metallurgical techniques allowing solvent extraction of zinc from oxidized ores are being successfully applied in several mines worldwide, so these large volumes of unmined zinc oxide ore in the upper parts of the Ojuela mine may attract renewed mining activity in the relatively near future. This would clearly have a favorable impact on specimen production, as long-backfilled areas would be cleaned out and new areas of oxide mineralization revealed for collecting.

Workings

The underground workings of the Ojuela mine are vast and deep. Upon first seeing the site one naturally speculates that the high mountain knob of the Bufa de Mapimí, on which the ruins of the miners' village are perched, must be honeycombed with stopes. Indeed it is, but in reality that massive prominence contains but a tiny proportion of the total workings. Figure 30 shows a vertical section through the Ojuela mine deposits, with many (but not all) of the major orebodies projected onto a vertical plane. To the tourist looking back over the bridge from the South Camp side, the view seems grandly panoramic enough (see frontispiece photo), but in scaled comparison with the chimneys and mantos of ore—beasts flailing great arms in the dark below—such human works seem entirely trivial. And unfortunately the extant mine maps are frustratingly incomplete and vague today; some of the underground workings are known only to the surviving miners who once worked (or still work) there, and some are no doubt unknown to any living person today.

Peter Megaw (in the Geology section, above) has distinguished seven major ore chimneys: (1) the Ojuela (Paloma), (2) the San Vicente, (3) the San Ignacio (Monterrey), (4) the San Nicolas, (5) the San Judas, (6) the San Jorge-San Juan, and (7) the San Antonio (Cumbres) chimney. (The latter two are not shown on Fig. 30.) San Antonio, to the north, is called the Cumbres "inclined chimney" by McLeroy *et al.* (1977), and the Cumbres "manto" by Megaw (above)—either term will do, as chimneys are vertical and mantos horizontal, and Cumbres has a general dip of about 45°.

The huge La Paloma chimney is said by Villarello (1909) to lie "very near" the Ojuela, and the vertical section shows the two to be connected at depth. Rice (1908a) mentions two other "large chimneys" called San Pedro and Santo Domingo. The latter of these appears on a surface map in McLeroy *et al.* (1977), but the former is not mentioned by other authors; perhaps its name has changed. Two other major named structures are the San Carlos manto (or "vein") and the Santa Rita replacement-vein deposit. San Carlos is a twisting, interwoven network of small ore pipes, developed for about 200 meters along a band between 80 and 160 meters depth; it was exhaustively exploited, and its lowermost parts are now flooded (McLeroy *et al.*, 1977). Santa Rita is a mineralized fault zone, and "the only important deposit of a replacement-vein type at Ojuela" (McLeroy *et al.*, 1977).

Figure 28 shows a plan-view projection through the dense central part of the aggregate deposit. To the north, San Antonio (Cumbres) appears, as does a smaller outlying manto called La Luz. The San Ignacio chimney appears as if separate from the Ojuela, although the vertical section shows them to merge at depth. The two other dense mining areas which show up on the horizontal section are called Socavon ("Entrance") and Campo Sur ("South Camp"); they were reached through the #4 shaft (Tiro 4), just beyond the south end of the Roebling suspension bridge. Modern-day tourists visiting the mine are taken across the bridge and into the opening on the south end; at times in the past this opening, now known as Tiro 4, was called the Socavon shaft (Rice, 1908a), and the workings it accessed were called the Socavon mine, or Socavon Viejo ("Old Entrance") mine. The Santa Rita replacement vein, though not shown on this map, is part of this Socavon complex (Southworth, 1905). The Campo Sur group of workings was sometimes delineated as being separate from the Socavon workings, as indicated in the Figure 28 map; farther to the south the San Judas chimney (which has no surface expression) was in turn considered to be part of Campo Sur.

The central, largest, and richest of all the ore chimneys exploited in the Ojuela mine complex was the one called (appropriately) the Ojuela, or Ojuela Vieja ("Old Ojuela"), chimney. According to McLeroy *et al.* (1977), this was the first deposit discovered by the Spanish explorers 400 years ago. Indeed the Spanish Descubridora ("Discovery Hole") opening directly under the bluff and near the bottom of the arroyo, is easily imagined to have intersected the Ojuela mineralization at depth. The Peñoles miners, who called this ancient opening the Boca Mina ("Mine Mouth" or "Mine Opening"), continued to use it to reach the Ojuela Vieja ores from one side, while also reaching them from the other side via the San Carlos adit (see below).

The Ojuela chimney is ovoid, and nearly perfectly vertical, reaching its greatest width at a depth of around 450 meters, splitting to enclose a giant "horse" of limestone just below that, and connecting, still further down, to the Paloma chimney. It is oxidized to a depth of about 500 meters, and already by the turn of the twentieth century it had been mined to a depth of 650 meters (Southworth 1905), with great hollow chambers remaining where the ore had been taken out. One of these huge stopes was intriguingly known as the Riscos Grotto (Villarello, 1909)—*Riscos*, meaning "treasure," is the term used today by miners of the *cooperativa* for collectible crystals, though in earlier times it probably referred simply to rich ore.

A few of the underground workings besides the Boca Mina no doubt date back to Spanish times or at least to the mid-19th century, but all of the most important tunnels and drifts date from the decades of large-scale mining by the Peñoles Company. Around the turn of the 20th century, five main working shafts were in operation. The southernmost was the Santa Rita shaft; at the south end of the Roebling suspension bridge, as already mentioned, was Tiro 4; on the other side of the arroyo and to the north was the Monterrey shaft; and in the valley to the northwest were the San Guillermo and America Dos shafts. More than a hundred less important shafts were also in operation at one time or another, including the North shaft, or Tiro 3, sunk near the north end of the Roebling bridge (see Fig. 30). Old photos show a headframe there, the ruins of which are still visible today.

The America Dos shaft, also called Tiro 2, was sunk around 1900, at approximately the same time that the huge San Carlos adit (following the San Carlos manto/vein) was driven, and the numbering system for the mine levels was changed. Before this time, ore mined at all levels would invariably be raised directly to the surface, but under the new system the ore was lowered or raised from other workings to San Carlos adit on Level 5 (formerly Level 12), then trammed to the America Dos shaft to be hoisted out of the mine.

The San Carlos adit connected mining areas in the Ojuela, San Ignacio, Socavon and San Judas pipes—practically the whole underground expanse of the Ojuela complex. The 1200 miners who worked underground each day were lowered down the shafts, and ore was brought up via the same shafts, in one-ton buckets or self-dumping skips, either to the surface or (increasingly after 1900) to the San Carlos adit. Rice (1908b) reported that the machinery worked so efficiently that it took only about two minutes for a loaded ore bucket to be hoisted from the 550-meter level to a surface site, dumped, and returned.

America Dos, the only shaft with two compartments, was timbered with 8 x 8-inch shaft sets to provide firmer anchorages for the hoisting system. The other shafts and most of the tunnels, adits and crosscuts remained for the most part untimbered; the Cuesta del Cura limestone is very hard, and bad ground was rare. The America Dos shaft, however, had a ground-stability problem, because part of it cut through the Indidura Shale. For many years

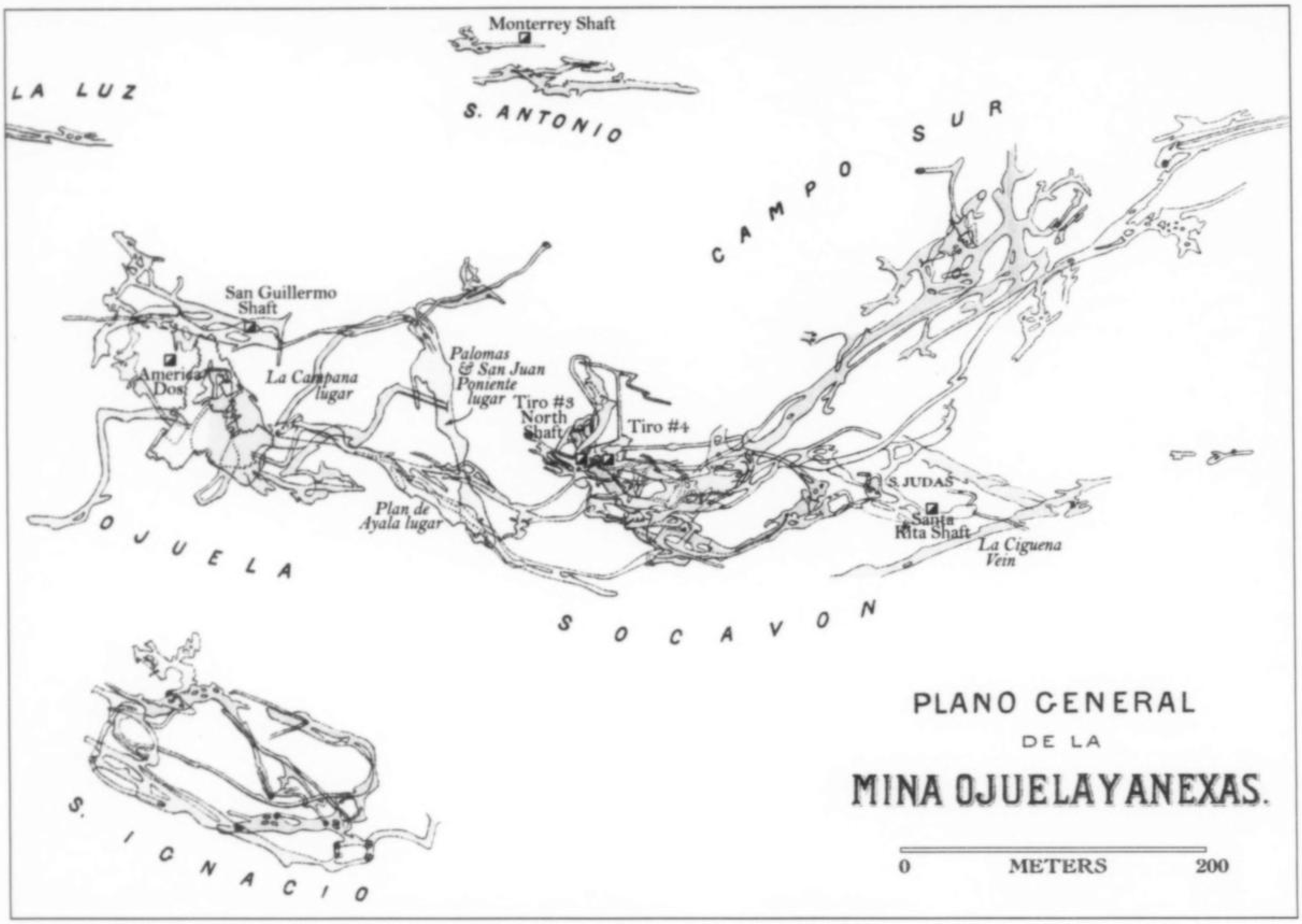


Figure 28. **Plan-view projection of some of the major orebodies in the Ojuela complex. (Compare Fig. 31) From Villarello, 1906.**

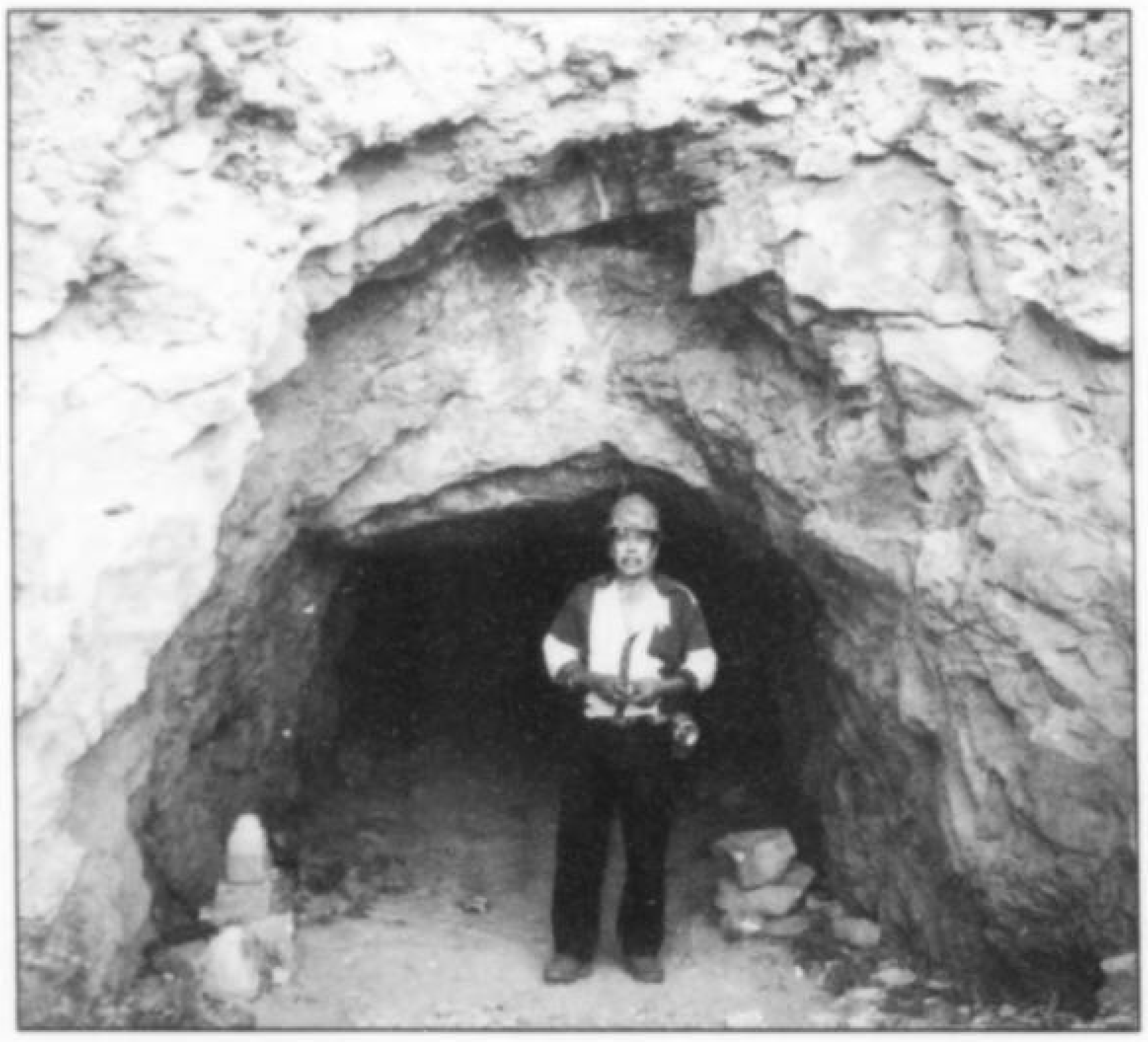


Figure 29. **Mario Pisena at one of the entrances to the San Carlos adit, November 2002. T. Moore photo.**

after the cessation of large-scale mining, the men of the *cooperativa* used the America Dos (and Monterrey, and several of the old entrances to the San Carlos adit) to enter the workings; but the miners of Top Gem no longer use America Dos, since a few years ago a part of the shaft gave way, at a point where it ran through the shale.

In the heydays of mining, steam generators furnished current to keep the workings electrically lighted, to power the hoists and diamond drills (see below), and to electrify the miners' village. Main crosscuts extended from the shafts at irregular intervals above the 450-meter level, and below that at regular intervals of 50 meters down to the 800-meter level, near the mine's "bottom" (Rice, 1908b). Ore cars on tracks provided underground transportation along these passages. But since the deposit itself is so labyrinthine, with countless small ore veins threaded around and between larger structures, and since nearly all of the mineralization is "blind," i.e. without surface expression, much ore was found simply because the Mexican miners followed the veins where they led, as their predecessors had done since Spanish times. The Peñoles Company was wisely content to allow these miners to keep gophering into the winding veins with their short-handled picks and scrapers, then load the ore out on their backs to be dumped into ore cars in the adits and drifts; in the slightly wider veins the miners used long-handled hoes to fill small pans with ore, then unloaded the ore from the pans into the ore cars. Impracticable in earlier times, these old-fashioned Mexican methods proved to work well in the context of Peñoles' modern industrial operation. By all accounts, general morale was consistently high: Rice (1908b) reported that sometimes, on the 4th of July, American shift bosses put up prizes for car-loading contests between *peones*, and that "with several *peones* in the contest, each busy with a hoe and pan, such a contest becomes almost as exciting as a double-hand drilling contest."

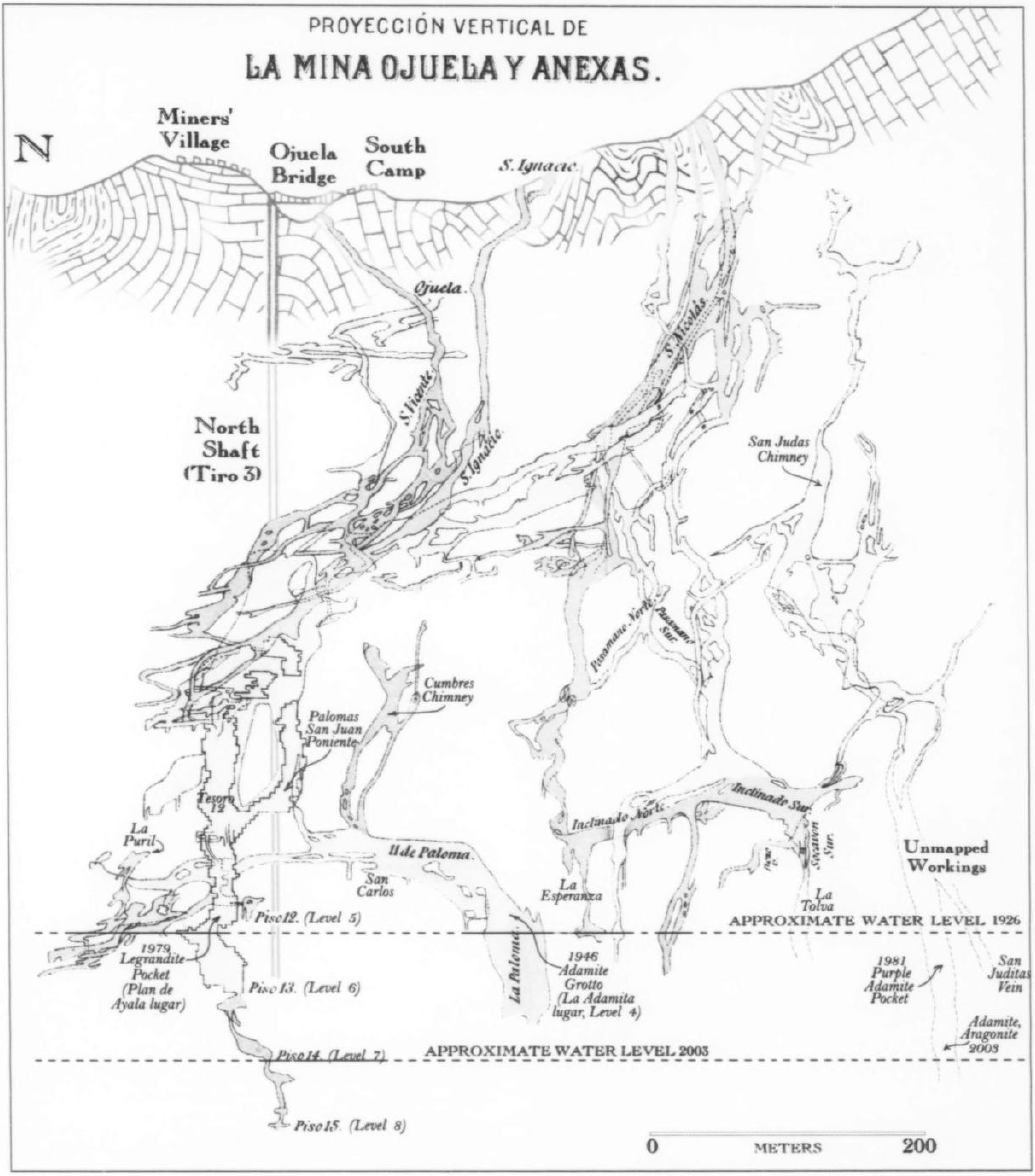
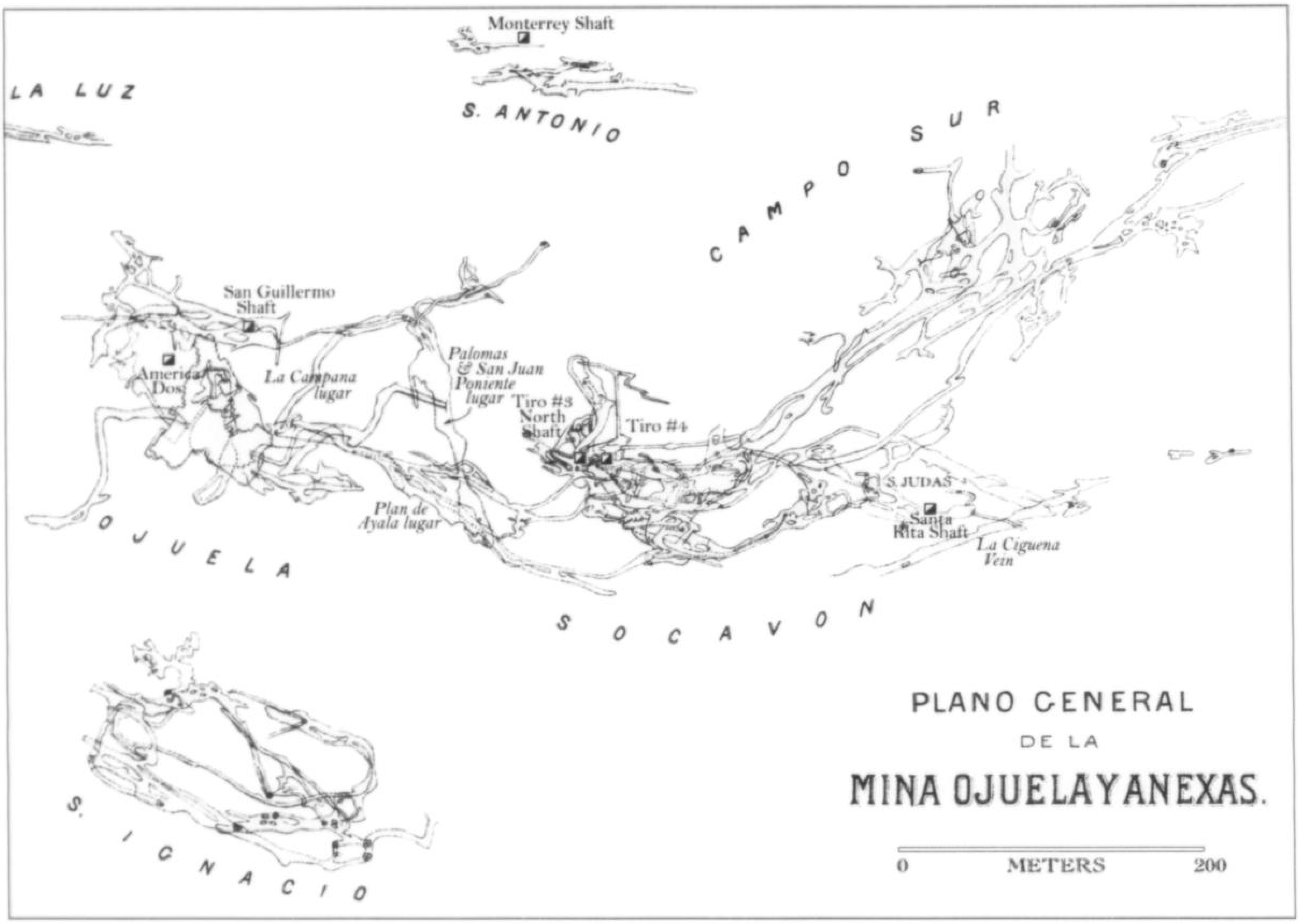


Figure 30. **Vertical north-south section showing the projection of some of the Ojuela-complex orebodies; compare Figure 30 (adapted from Villarello, 1906, and Prescott, 1926 with lugares as indicated by Mike New and his miners, pers. comm. 2003).**

New mineralization was continually sought by prospecting with diamond drills from the tunnels and drifts. Before 1900 this was done by a method whereby 120-meter squares were blocked out for systematic drilling along successive stages of tunnel, but then a better, if less systematic, method was found in which drill holes were made from a series of informal "set-ups." The hole positions, together with any findings concerning the ground ahead (inferred from the sludge which emerged; drill cores were not saved) were recorded on index cards, and from these data special maps were constructed to extrapolate mineralization. This very modern approach to prospecting made a paradoxical complement to the eyeballing investigations of the common miners.

By the time industrial mining ended, an extremely extensive and complex system of underground workings had been created. Since



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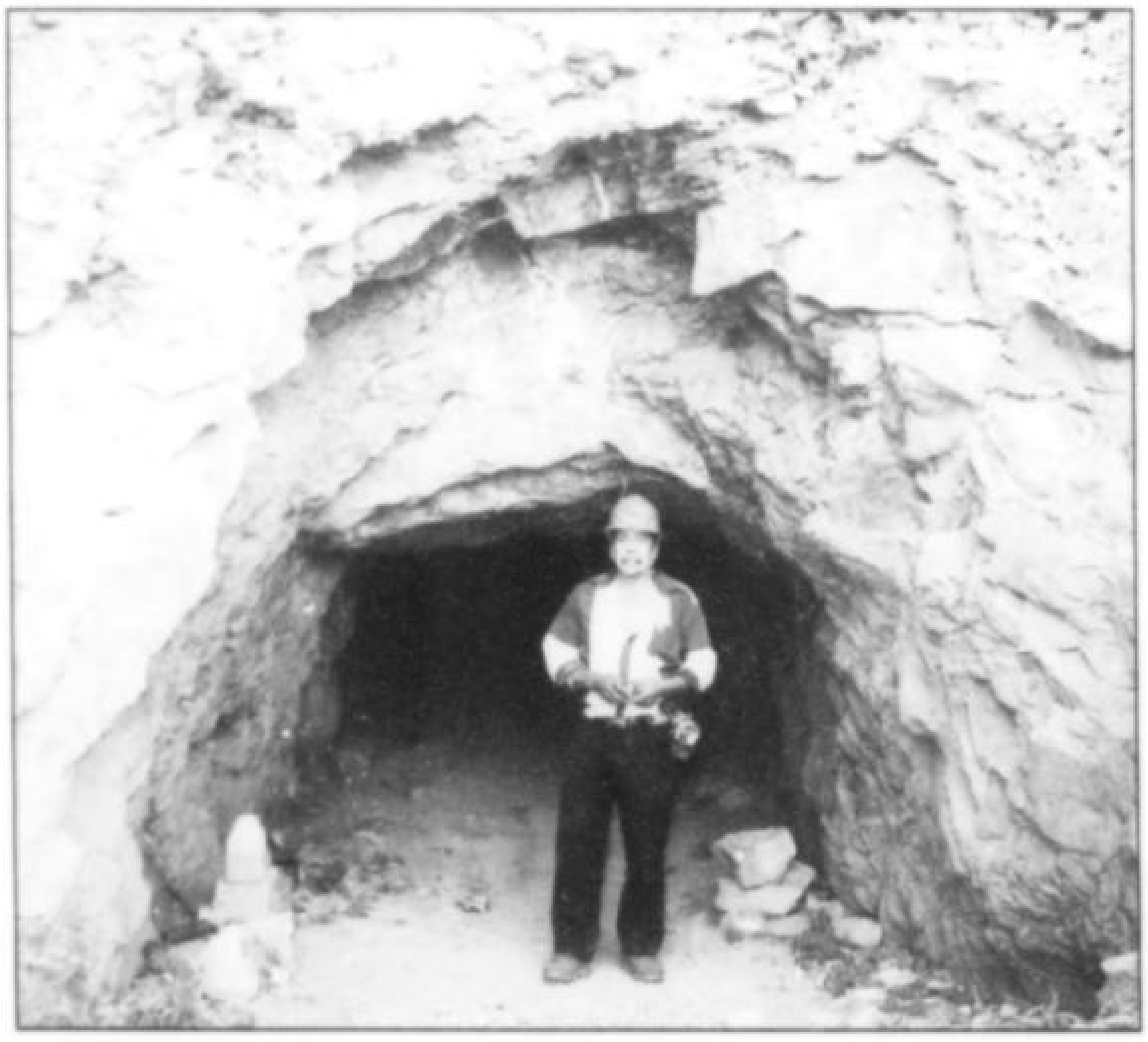

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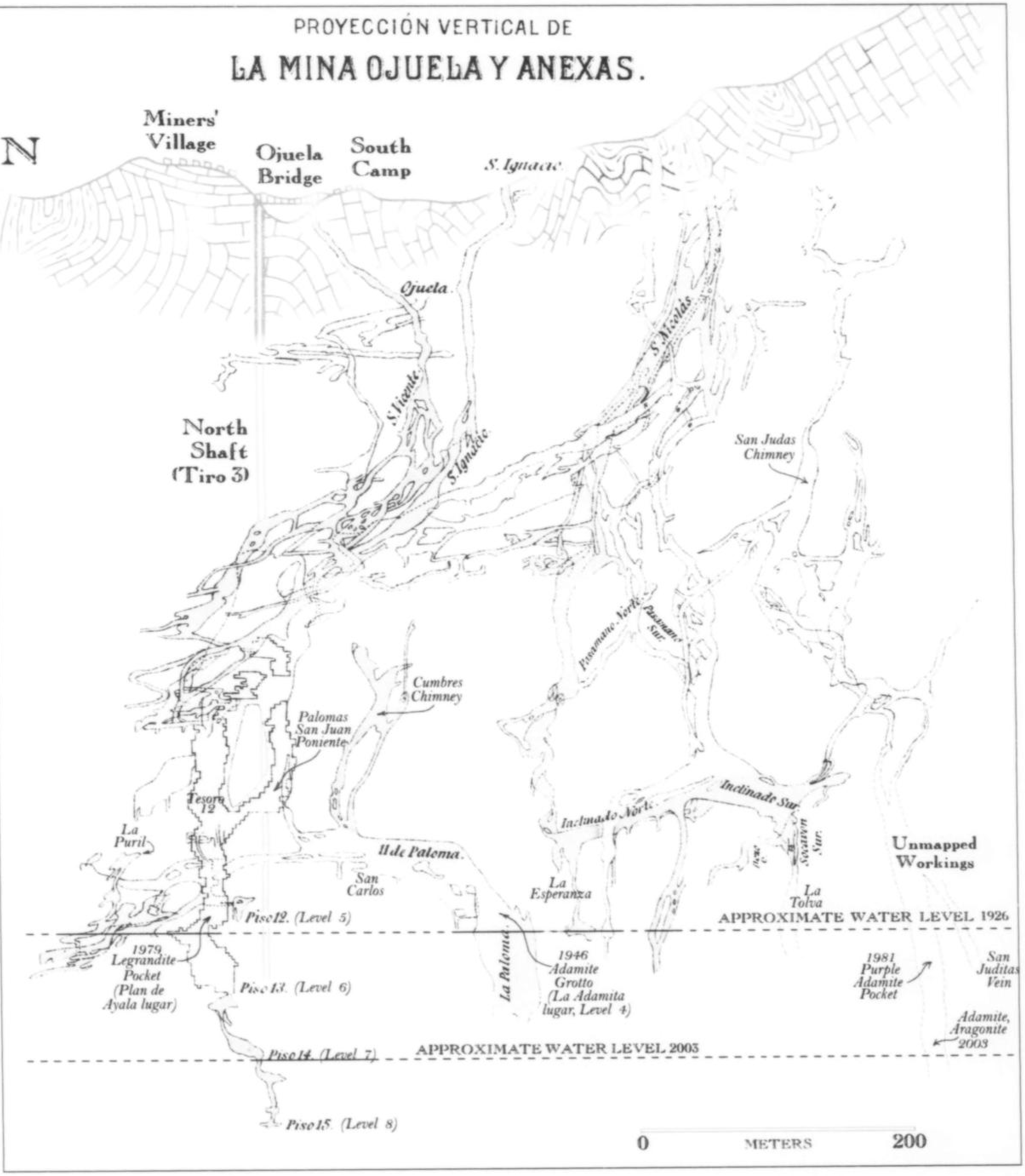

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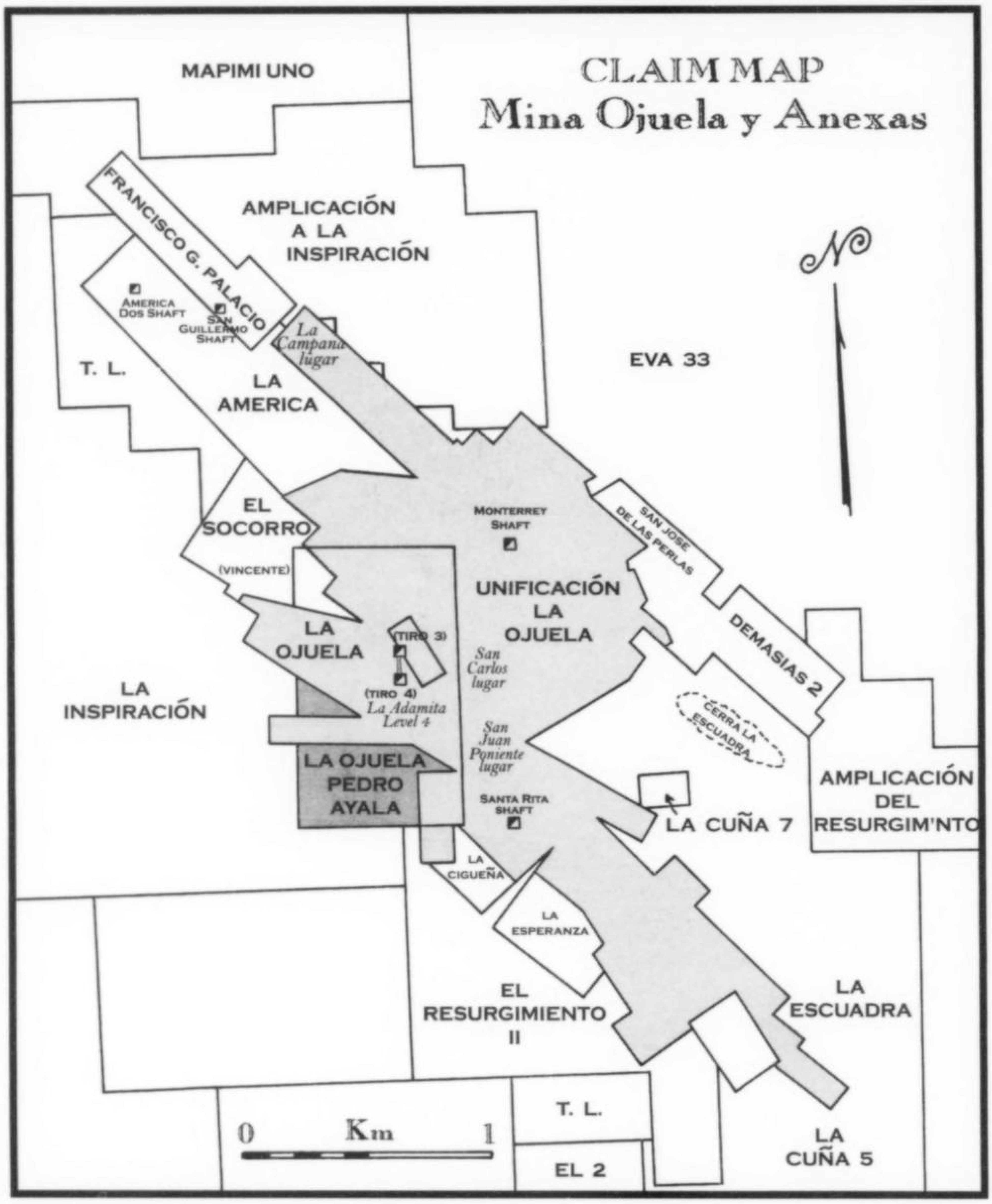


Figure 31. **Surface plan of the Ojuela mine and surrounding area, showing major claims existing today (adapted from an unpublished map by the Peñoles Company, augmented by first-person information obtained from miners and Mike New). Pale gray=Peñoles property. Note suspension bridge Tiro 3 and 4.**

1945, no new workings of any significance have been added. The miners of the *cooperativa* (and, later, Top Gem's miners) have been content to find their way to interesting collecting spots underground via the old workings left by Peñoles. Many old maps are vague, inaccurate, or not to be located; some of the 450 kilometers' worth of tunnels, drifts, and gopher-holes were never mapped in the first place; much ground has given way, to form perilous slumps and collapsed areas; many a helpful chicken ladder now lies fallen and/or buried. We may be sure that all of the specimens which emerge from the Ojuela mine in the future will have been won at significant risk by brave men willing to enter the labyrinth.

Minerals

The following listing surveys all known species from the Ojuela mine (except for rock-forming minerals of the country rocks), and a few specimen-worthy occurrences in other, smaller mines in the Mapimí district. **Names of district mines other than the Ojuela are shown in bold type**, and will be mentioned in connection with some of the more interesting minerals which they produce. *Names for collecting sites within the Ojuela mine are shown in italics;* these are what the miners call the Ojuela *lugares (see table 1).* The Spanish word *lugar* means "place" or "site," and in Mapimí it denotes a worksite, i.e. a place large enough to mine. Thus, most of the names of *lugares* are informal, created by the miners themselves, although some can be correlated with the names of chim-

Figure 32. **Old entrance that intersects the San Carlos adit, November 2002. T. Moore photo.**

Figure 33. **Mined-out stope in limonite off the San Carlos adit, November 2002. T. Moore photo.**

neys or mantos in the Ojuela deposit; e.g. the *lugar* called *Cumbres* lies in the San Antonio ore chimney (also called the Cumbres orebody). Some italicized terms denote sites which older sources list as "mines," but which belonged, or now belong, to the Ojuela mine complex: e.g. the "Monterrey mine" of Hoffmann (1967) is an orebody within the San Ignacio chimney in the Ojuela mine, and is considered here as a *lugar.* Sometimes names have simply changed; e.g. the "North Shaft" of Foshag (1937) has more recently been called the America Dos Shaft, and is here called *America Dos* (for many years this was the miners' primary entrance to the Ojuela mine's system of underground workings).

Two systems have historically been used to number levels of the Ojuela mine. The older system starts at the surface and distinguishes levels approximately every 50 feet. The more recent system, established after Peñoles completed the San Carlos adit at canyon-level, distinguishes levels every 100 feet. What used to be called Level 12 is now Level 5. The newer system is used in the present work.

Every attempt has been made to offer specific information on which species came from where in the Ojuela mine, and when they did so, and, for very widely distributed species, which color, habit, associations, etc. were found in which *lugar*, and when. Approximate locations of the *lugares* are shown on the underground mine map. When information of this sort is not accompanied by a citation to the literature, it has come from oral accounts by the miners and by Mike New and is based in their firsthand collecting experiences.

Unfortunately, many Mexican specimens on the market which are in fact *not* from the mine have been labeled "Ojuela mine" or perhaps "Mapimí" (and the collector's dark angel tempts him, in this case, to add "Ojuela mine" all on his own). Misattribution of specimens to a famous locality, especially one of diverse and complex mineralogy, is a familiar problem in many different geographic venues of interest to the mineral collector. Specifically, many an "Ojuela" mimetite specimen seen on the market is in fact from Velardeña: this locality produced huge quantities of pale green mimetite, routinely sold through Bermejillo as being from Mapimi. Many other "Ojuela" mimetites and smithsonites are actually from Santa Eulalia; many an "Ojuela" pyromorphite is from the San José mine, Guazapares, Chihuahua, or from Zimapán,

Table 1. **Important *lugares* (collecting areas) in the Ojuela mine, and the species found in each.**

America Dos (incl. dump)
- Anglesite
- Arseniosiderite
- Austinite
- Calcite
- Carminite
- Chalcocite
- Hausmannite
- Hydrohetaerolite
- Malachite
- Mimetite
- Stibiconite
- Stibnite

America Poniente
- Calcite
- Hydrozincite
- Litharge/Minium
- Mimetite
- Murdochite
- Plattnerite
- Rosasite (best)
- Wulfenite

Campana
- Calcite
- Mimetite
- Wulfenite

Cumbres (San Antonio chimney)
- Aurichalcite
- Azurite
- Copper
- Cuprite
- Malachite
- Rosasite

El Pirul
- Brochantite

La Cigueña
- Adamite
- Calcite
- Carminite
- Smithsonite/goethite (ps. aft. legrandite)

La Esperanza
- Adamite
- Calcite
- Chalcophanite
- Fluorite
- Hemimorphite
- Murdochite
- Plattnerite
- Smithsonite

La Tolva
- Adamite

Level Four
- Adamite (first discovery)
- Cerussite
- Mimetite
- Smithsonite

Level 5 between Palomes Oriente and San Carlos (incl. "Los Changos")
- Austinite
- Calcite
- Gypsum
- Köttigite/Parasymplesite,
- Legrandite
- Mapimite
- Ojuelaite
- Paradamite
- Pharmacosiderite
- Smithsonite

Monterrey
- Berzelianite
- Bismuth
- Bismuthinite
- Cassiterite
- Diopside
- Emplectite
- Enargite
- Galena
- Marcasite
- Pyrrhotite
- Sphalerite
- Stannite
- Umangite

Number Nine
- Adamite

Palomes Oriente
- Adamite
- Austinite
- Gypsum
- Jarosite
- Köttigite/Parasymplesite
- Legrandite
- Mapimite
- Ojuelaite
- Paradamite
- Smithonite (best)

Plan de Ayala (Level 5.5)
- Legrandite (best)
- Scorodite
- Tsumcorite (?)

San Carlos (Level 2 = "Manganeso")
- Barite
- Calcite
- Conichalcite
- Fluorite (best)
- Hemimorphite

San Diego Stope, Level 6
- Bindheimite
- Mimetite
- Plumbojarosite
- Wulfenite

San Juan
- Austinite

San Juan Poniente (incl. Dump)
- Adamite
- Anglesite
- Aurichalcite
- Azurite
- Barite
- Bindheimite
- Brochantite
- Calcite
- Carminite
- Cerussite
- Chenevixite
- Conichalcite
- Cuprite
- Gypsum
- Hausmannite
- Hedyphane
- Hemimorphite
- Hydrohetaerolite
- Malachite
- Mimetite
- Pharmacosiderite
- Plumbojarosite
- Rosasite
- Silver
- Wulfenite

San Judas, Level 5
- Adamite
- Hemimorphite (best)

San Judas, Level 6
- Adamite (incl. purple, best)
- Arseniosiderite
- Chalcophanite
- Chlorargyrite
- Hemimorphite
- Lotharmeyerite
- Mn analog of arseniosiderite
- Manganlotharmeyerite
- Ogdensburgite
- Scorodite (best)
- Smithsonite
- Villyaellenite

San Judas, Level 7
- Adamite
- Aragonite

San Juditas
- Adamite
- Arsendescloizite
- Calcite
- Litharge/Minium
- Mimetite

San Rafael
- Lepidocrocite

Santo Domingo
- Hemimorphite
- Libethenite

Socavon Shaft
- Hemimorphite
- Sauconite

Tesoro Doce, Level 5
- Adamite

Hidalgo—smithsonite and pyromorphite are very rare in good specimens from Mapimí. Well crystallized sulfides in hand-specimen sizes are practically unknown from the Ojuela mine, although good large specimens of pyrite from Conception del Oro, pyrrhotite from Santa Eulalia, and stibnite and jamesonite from various mines in Zacatecas have all been sold as "Ojuela mine" or "Mapimí" specimens. Fine, large celestine crystals do indeed occur at mines in the Mapimí district, but not in the Ojuela mine. Dealers who misattribute specimens in these ways do not, of course, necessarily do so with conscious dishonesty; more likely they are only repeating what they have been told by a supplier, or they have assumed that a specimen *sold* in Mapimí must have come from the Ojuela mine. It is hoped that the listing below will help collectors and curators to address such mysteries and ambiguities in their own collections.

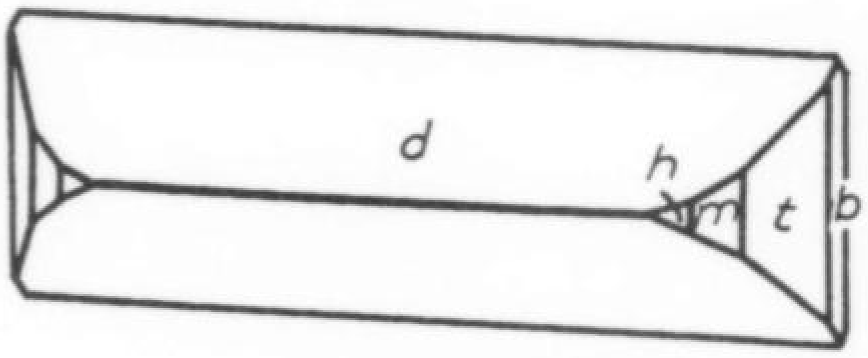


***Figure 34.* Crystal drawing of adamite from the Ojuela mine. *b*{010}, *t*{120}, *m*{110}, *h*{210}, *d*{101} (Mrose, 1948).**

Adamite $Zn_2(AsO_4)(OH)$

The Ojuela mine is far and away the world's most prolific producer of outstanding crystal specimens of adamite. The species was first described by Charles Friedel in 1866, and named after the Parisian mineralogist Gilbert-Joseph Adam (1795–1881), who provided the type specimens from Chañarcillo, Chile. Ojuela adamite occurs in vugs in dark brown goethite, less commonly on white limestone, primarily in stopes between the 4th and 15th levels of the mine (Megaw, 1996). Individual crystals reach 12 cm (Panczner, 1987), but more common and more familiar to most collectors than sharply individualized single crystals are the great fans or spherical or hemispherical aggregates (often called "wheels") of brilliant yellow-green radiating crystals on goethite matrix. The most commonly associated species on such specimens are calcite, smithsonite, conichalcite, hemimorphite and legrandite (Hoffmann, 1967), although Cook (1999) observes that the best adamite in the Ojuela mine tends to occur without associated species, except for a few fine specimens on which legrandite or smithsonite appears. Single adamite crystals are commonly elongated parallel to [010], [001], and rarely [100] (Cook, 1999), but some crystals are shortened parallel to the *b* axis and are pseudo-octahedral or tabular. The dominant form is {101}; additional forms include {120}, {110}, {210}, and {010} (Hoffmann, 1967).

Chemical analyses carried out by Mrose (1948) show that the yellow adamite from the great grotto on Level 4 is very pure, conforming closely to the ideal formula; this was the first major discovery of adamite in the mine. However, Ojuela mine adamite can contain trace elements, and these are responsible for the occurrence of adamite in other attractive colors.

In 1981, on Level 6 in *San Judas*, an extraordinary find of royal-purple adamite crystals delighted collectors (Wilson, 1982b; Panczner, 1983a; Megaw, 1996); although Mapimí locals call the purple crystals "cobaltos," the chromophore is actually manganese (Megaw, 1996). Some crystals from this pocket are zoned, with pale yellow or yellow-green bases grading to pale or deep purple near the terminations (see sidebar, "Purple Adamite Tales").

In the late 1980's a remarkable pocket was found with cuprian, pale turquoise-blue adamite crystals, and then a second pocket with cuprian adamite crystals of a greenish blue hue to more than 1 cm (Wilson, 1989); these apparently were the first widely marketed finds of significant specimens of blue adamite from the mine, although pale blue drusy crystals of "cuproadamite" on goethite had been noted earlier (Johnson, 1962), and some blue crystals were discovered in 1969 (Miller and Olson, 1970; see below). Some of the specimens currently being mined in 2003 consist of highly lustrous, pale greenish blue adamite crystal sheaves to 2 cm on dense rust-red goethite matrix.

Golden-tan to rich brown, presumably ferrous, prismatic adamite crystals to 2 cm on drusy gray adamite in a red-brown limonite matrix were found in the early 1990's (Robinson and King, 1991), and more brown adamite crystals are being found today, some in rounded sheaves of subparallel crystals, some as sharp, blocky singles to 1 cm.

The well-known intense yellow-green fluorescence of some yellow adamite from the Ojuela mine is due to trace amounts of uranium (Modreski and Newsome, 1984); this fluorescence is generally more intense in the spherical crystal aggregates from the Level 4 grotto than in the large, individualized yellow crystals from other areas (Megaw, 1996). In the blue cuprian, brownish ferroan, and purple manganoan adamite crystals, fluorescence is dampened by the trace elements.

The history of adamite from the Ojuela mine seems to have begun in 1946, when Dan E. Mayers and Francis A. Wise came upon a huge grotto of crystals—see sidebar, "The First Discovery of Adamite in the Ojuela Mine." In the following year, the news broke modestly in the collector literature when Henry Dake, editor of *The Mineralogist,* inserted a small paragraph announcing "adamite found" (Dake, 1947).

During the early 1960's, "adamite was so common in the shops that it was easy to obtain flats of excellent quality for very reasonable prices" (Jones, 1970a). Robert Cook (1999) recalled that when he collected underground at the Ojuela mine in the early 1960's, he entered a stope measuring about 10 x 20 x 25 feet, and found an abundance of fine adamite specimens lying loose in the gossan on the stope floor. Interestingly, these included some purple crystals, well in advance of the great discovery in *San Judas* in 1981; indeed, Panczner (1983a) remarks that mineral dealers in the early 1960's occasionally offered purple adamite crystals of mediocre quality.

During the middle 1960's, adamite was encountered so abundantly in the mine that the co-operative's collectors, working in shifts, took out tons of specimens from what became known simply as "the adamite zone" on Level 4 (Mike New, personal communication, 2002). However, Bob Jones wrote (1970a) that in the middle 1960's there was "an almost phantom-like disappearance of this mineral from the market," so apparently the production was rather sporadic. In the summer of 1969, a pocket was excavated which probably contained more than two tons of fine adamite specimens of a variety of colors from almost colorless to rich blue-green (Miller and Olson, 1970). Because of this strike, "the market was again flooded, but the prices reflected the new respect for adamite. Cabinet specimens of top quality were selling for fifty dollars and more" (Jones, 1970a). Probably the adamite specimens noted in the very first "What's New in Minerals?" column in the *Mineralogical Record* (White, 1970a) were from this find, and in saying, contra Jones, that these were selling for "bargain prices" John White was accurate for the long haul: collectors today would

Figure 35. **Colorless adamite, 4 cm wide, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.**

Figure 36. **Colorless adamite composite crystal, 5 cm, from the Ojuela mine. University of Arizona Mineral Museum collection; Wendell Wilson photo.**

Figure 37. **Colorless to faintly yellow adamite crystal, 3.8 cm, from the Ojuela mine. Artrox specimen (1982); Wendell Wilson photo.**

Figure 38. **Colorless adamite "pinwheel," 2.1 cm wide, from the Ojuela mine. New Mexico School of Mining and Mineral Resources collection; Jeff Scovil photo.**

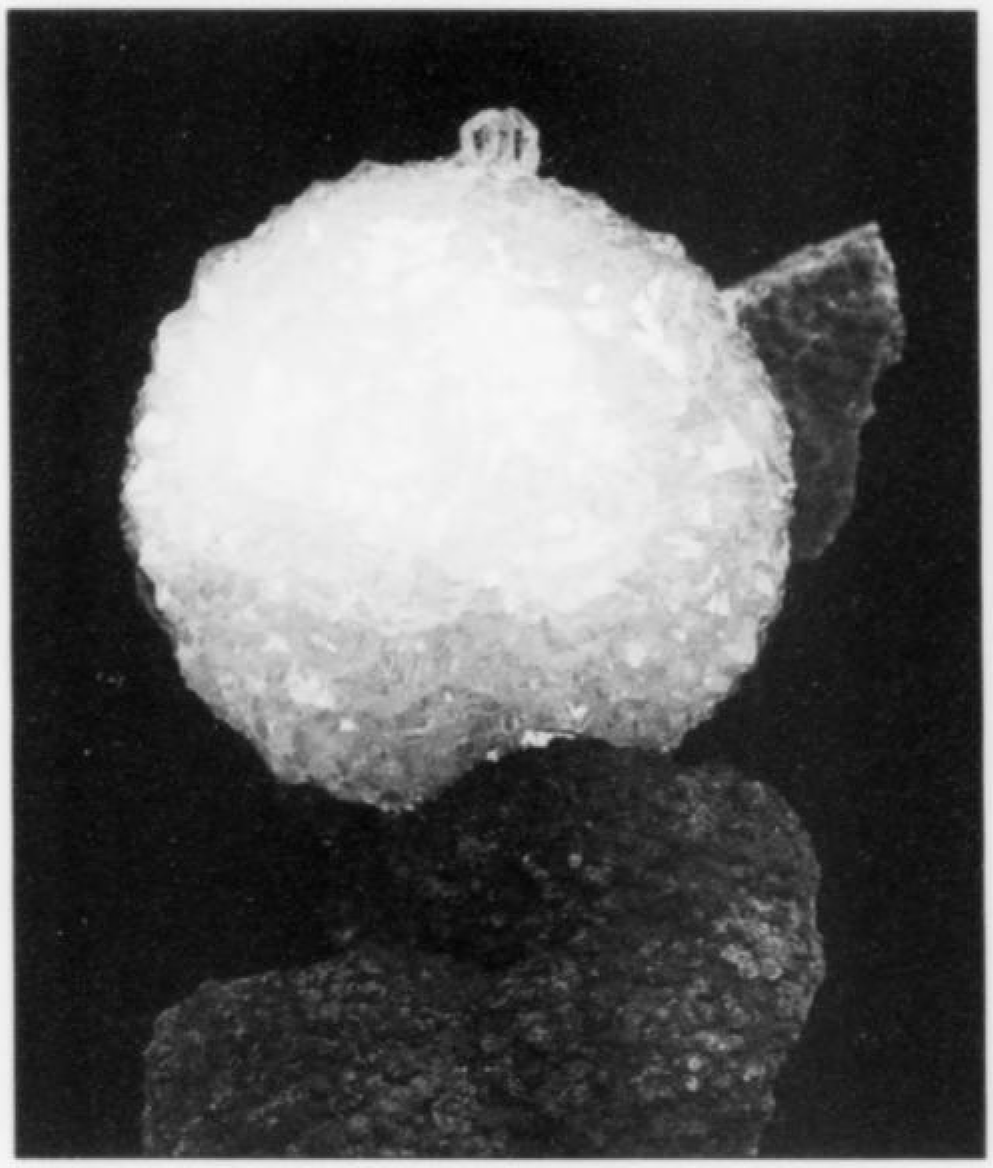


Figure 39. Yellow adamite sphere, 3 cm, from the Ojuela mine. F. Benjamin collection; Jeff Scovil photo.

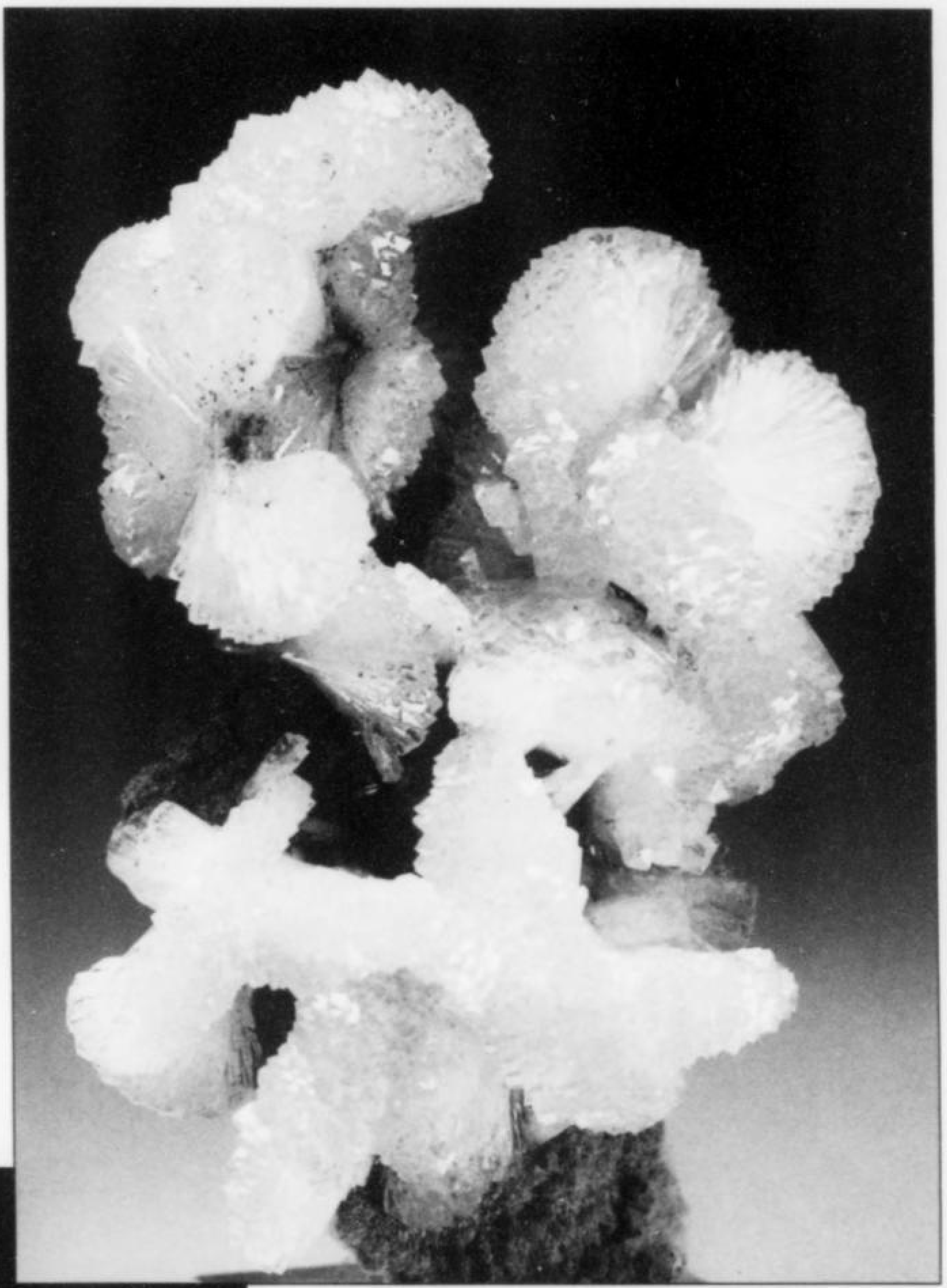


Figure 40. Cluster of adamite "fans," 6.1 cm, from the Ojuela mine. Wayne and Dona Leicht collection; Wendell Wilson photo.

Figure 41. Adamite spheres on matrix, 5.2 cm from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.

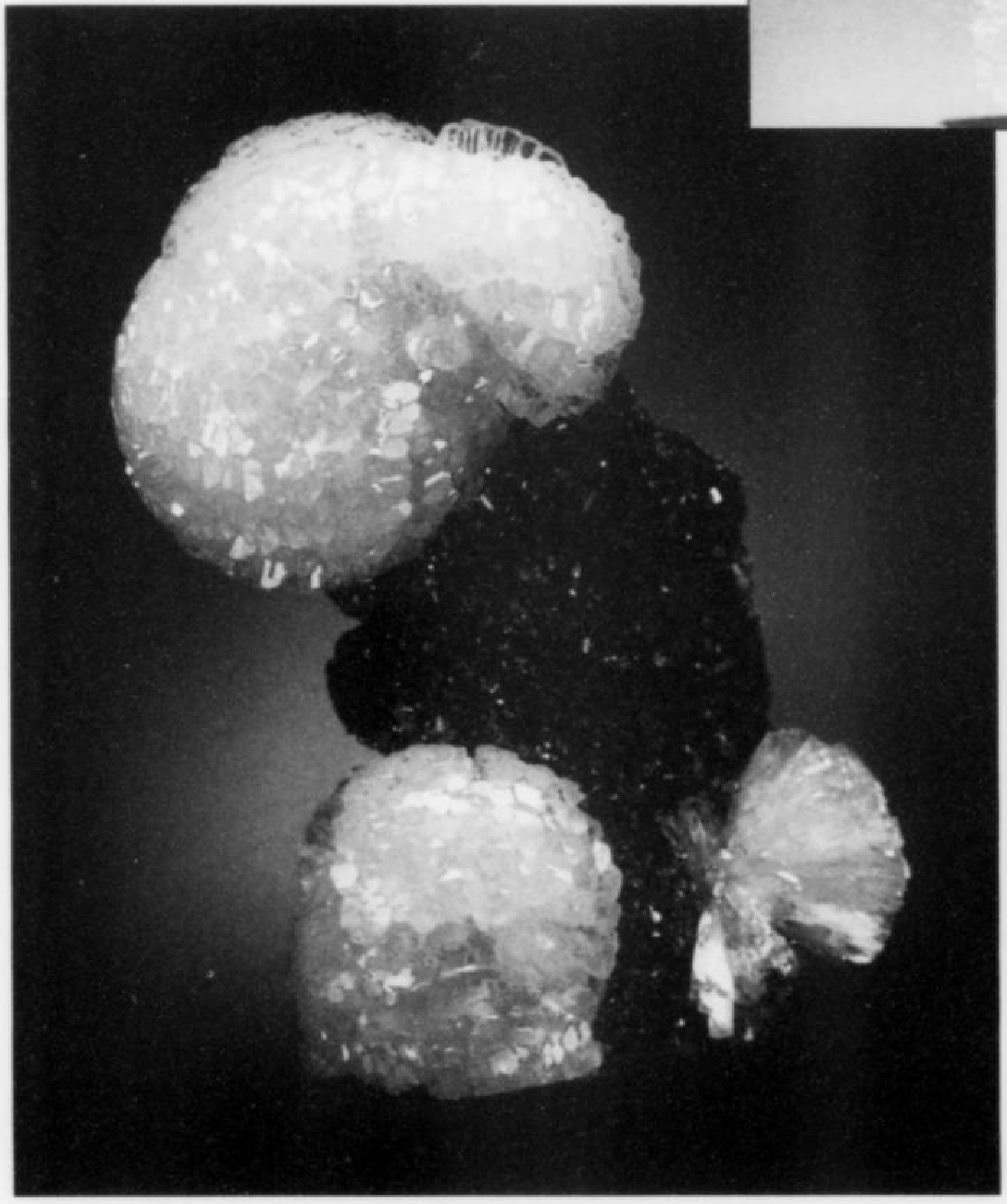


Figure 42. Adamite "pinwheel" on limonite, 2.1 cm, from the Ojuela mine. Ron Pellar collection; Jeff Scovil photo.

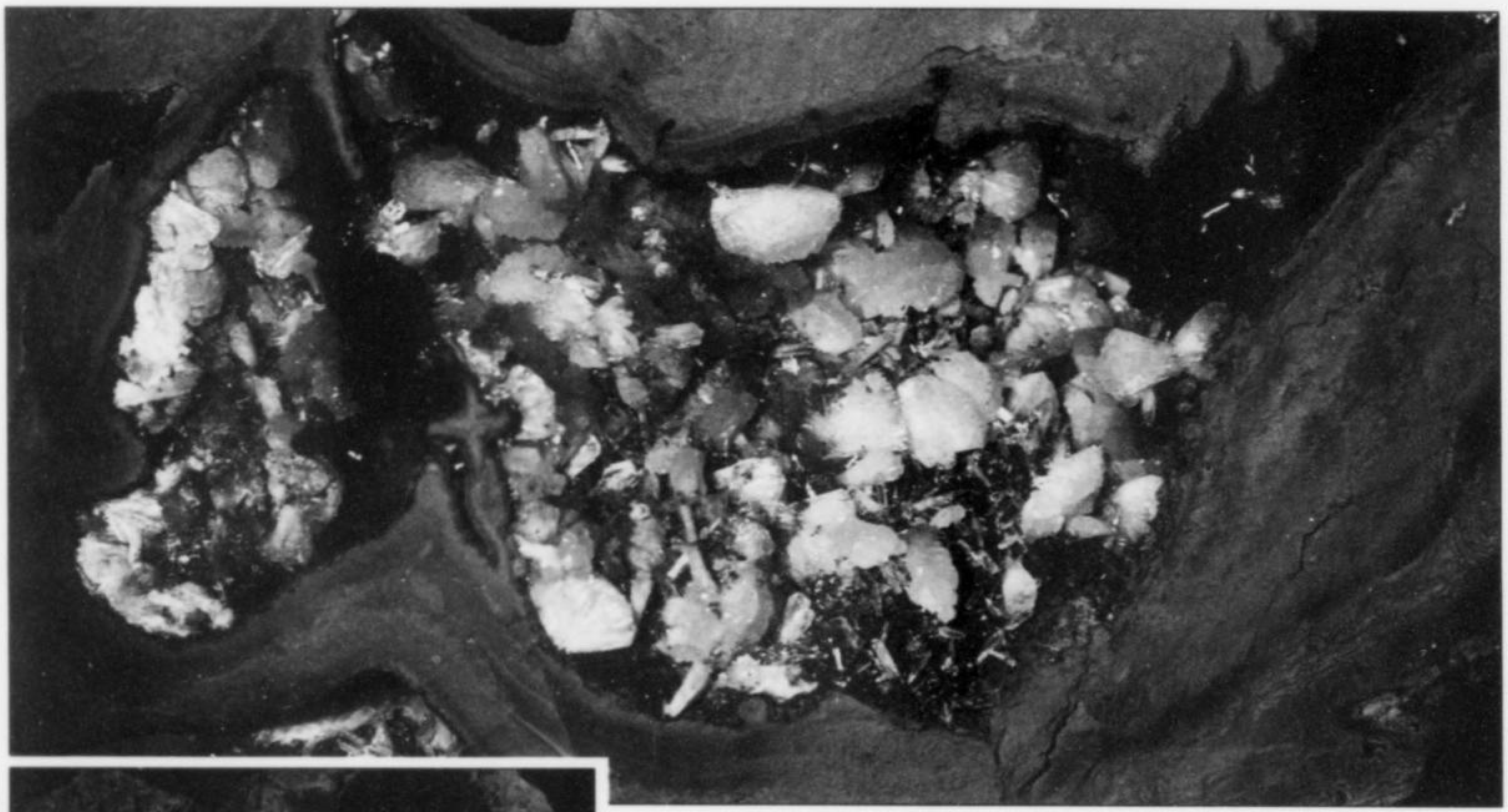


Figure 43. **Adamite pocket, about 35 cm across, from the Ojuela mine; exhibited at the Detroit Gem and Mineral Show, 1980. Wendell Wilson photo.**

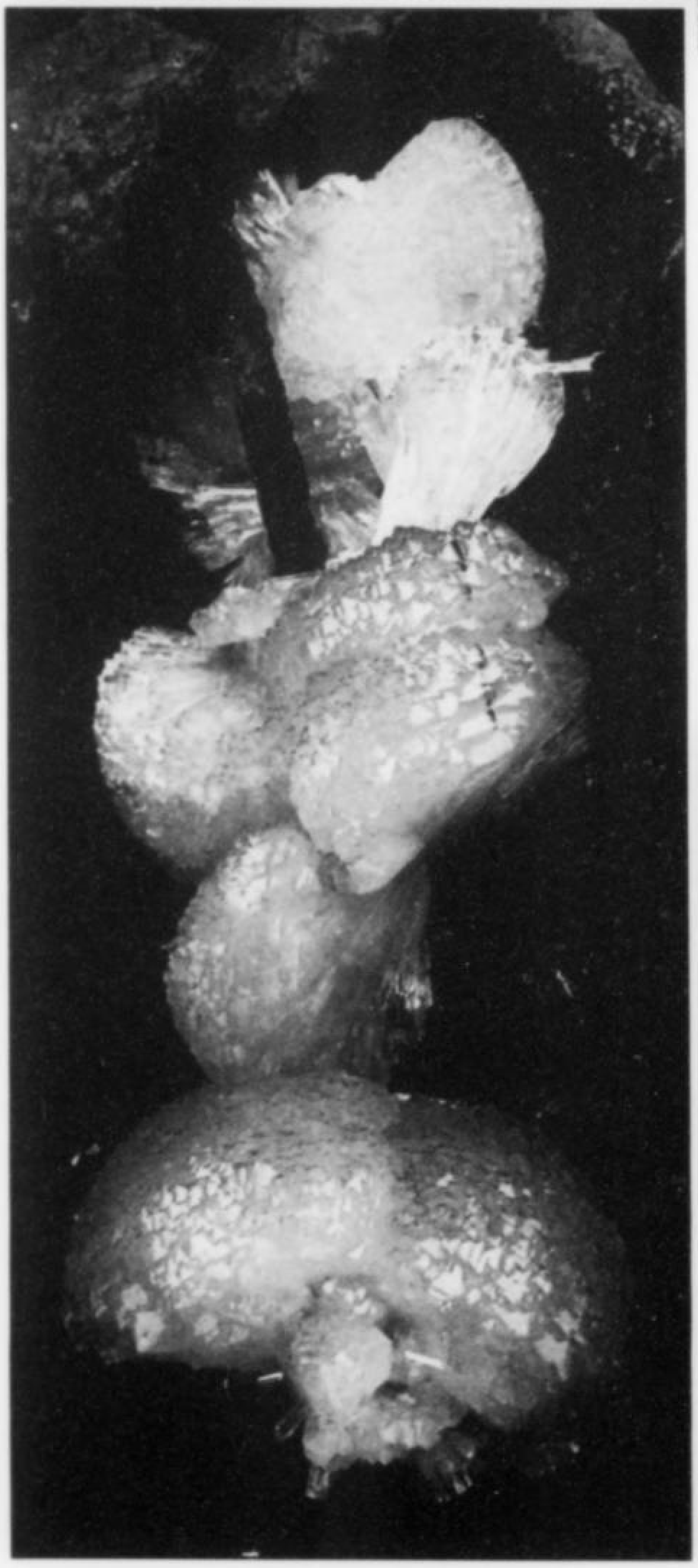


Figure 44. **Adamite clusters on limonite, 11 cm, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

Figure 45. **Adamite spheres on limonite, 6 cm, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

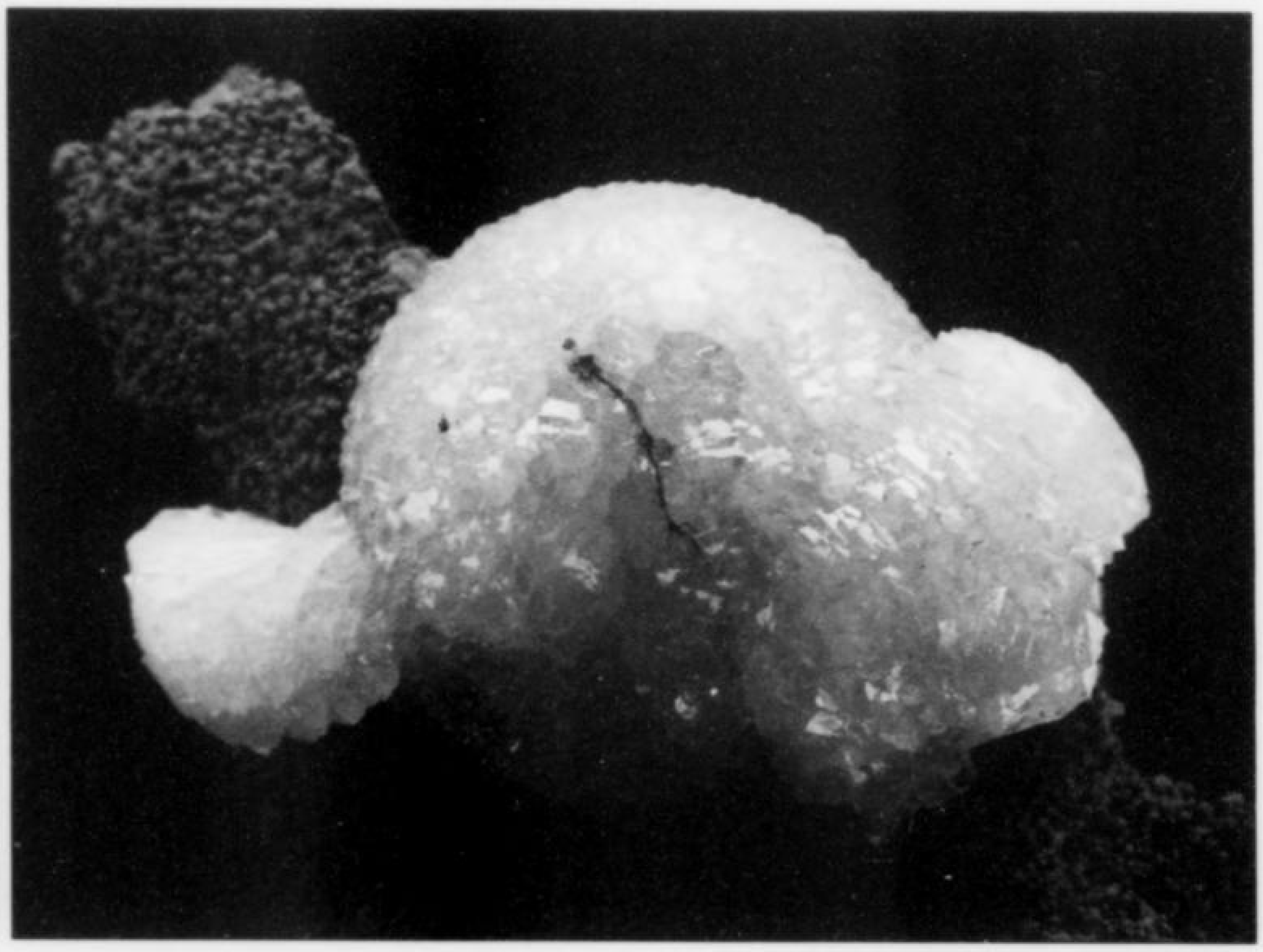


Figure 46. **Magnificent adamite pocket, 40 cm tall, from the Ojuela mine. Rare specimens of this size give a feeling for what a pocket in place looks like. Bruce Oreck collection; Jeff Scovil photo.**

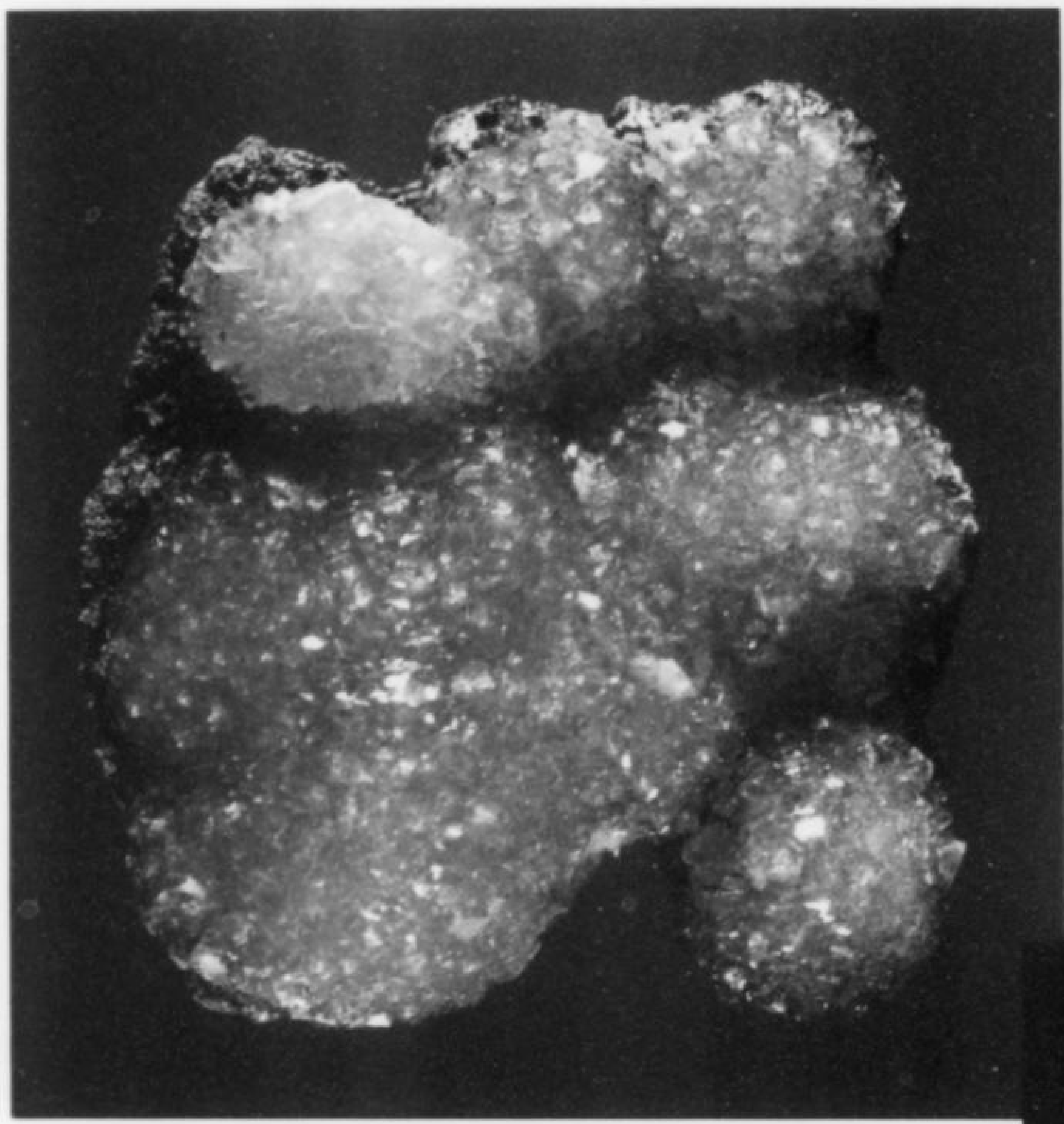


Figure 47. Cuprian adamite, 5 cm, from the Ojuela mine. Norm and Roz Pellman collection and photo.

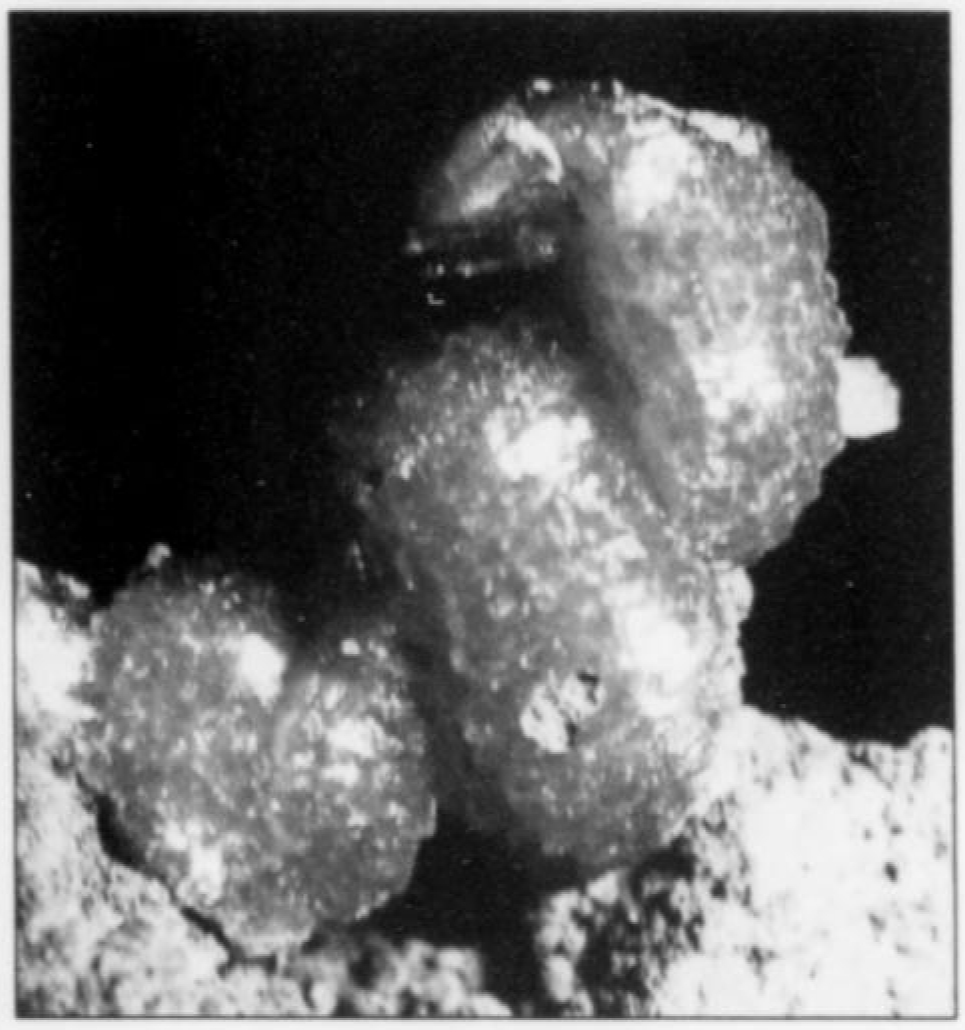


Figure 48. Cuprian adamite, 6 cm, Ojuela mine. Steve Blyskal collection and photo.

Figure 49. Cuprian adamite on limonite, 7 cm, from the Ojuela mine. P. and J. Clifford collection; Jeff Scovil photo.

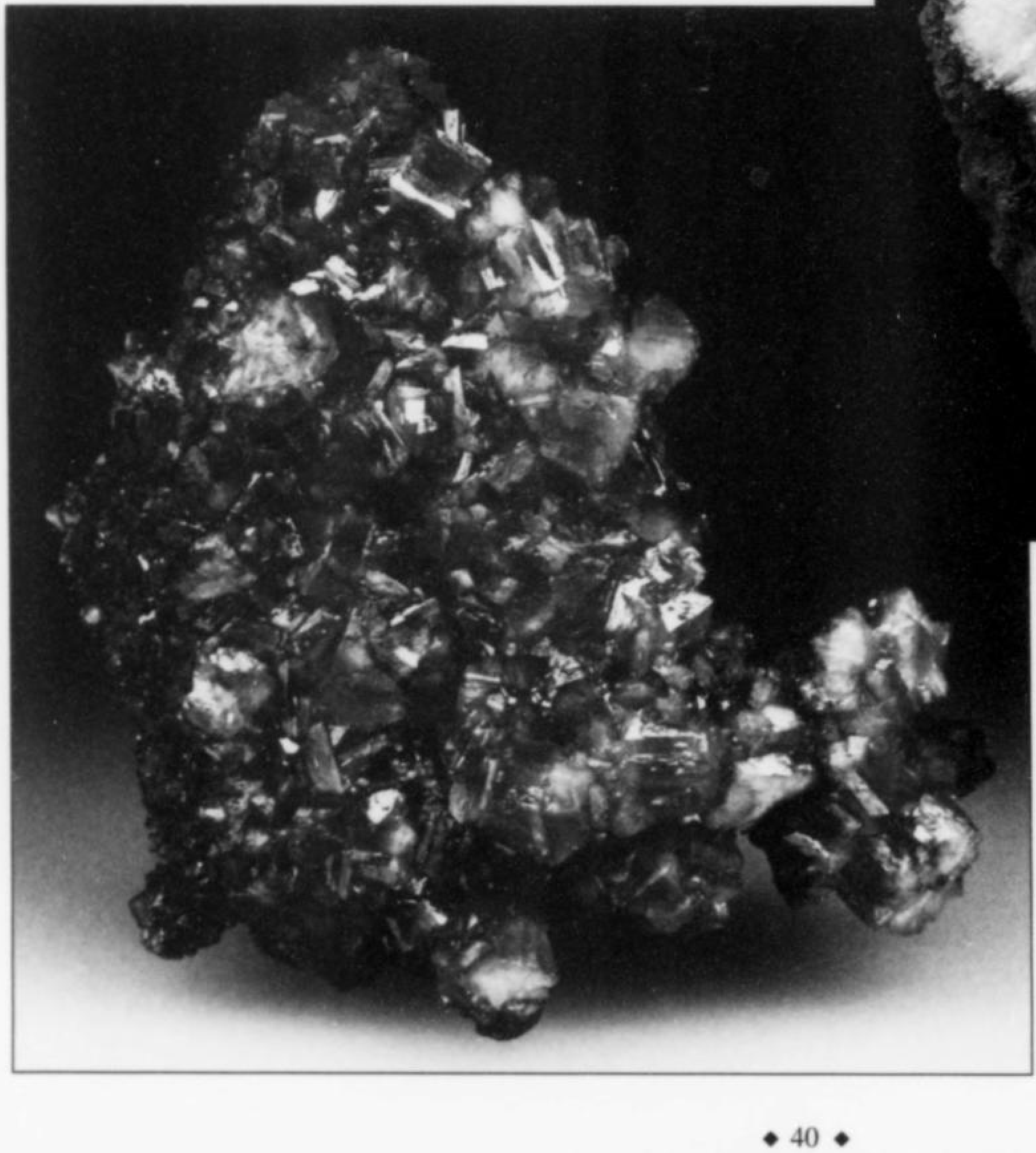


Figure 50. Cuprian adamite, 6.5 cm, from the Ojuela mine. Pat Hendrick collection; Jeff Scovil photo.

Figure 51. **Cuprian adamite, 3.1 cm across, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

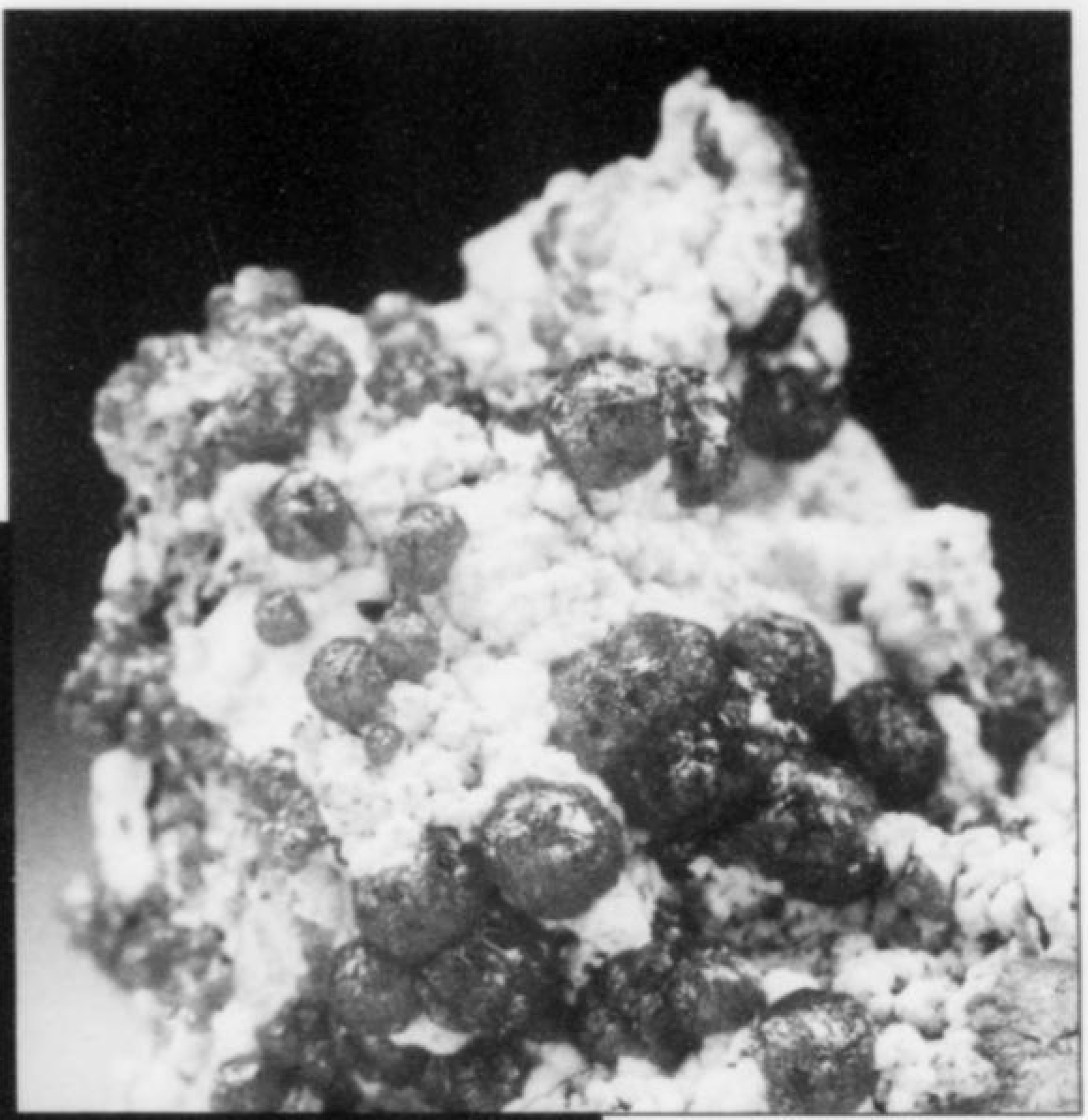


Figure 52. **Cuprian adamite on limonite, 9.7 cm, from the Ojuela mine. Miguel Romero collection, now in the University of Arizona Mineral Museum collection; Wendell Wilson photo.**

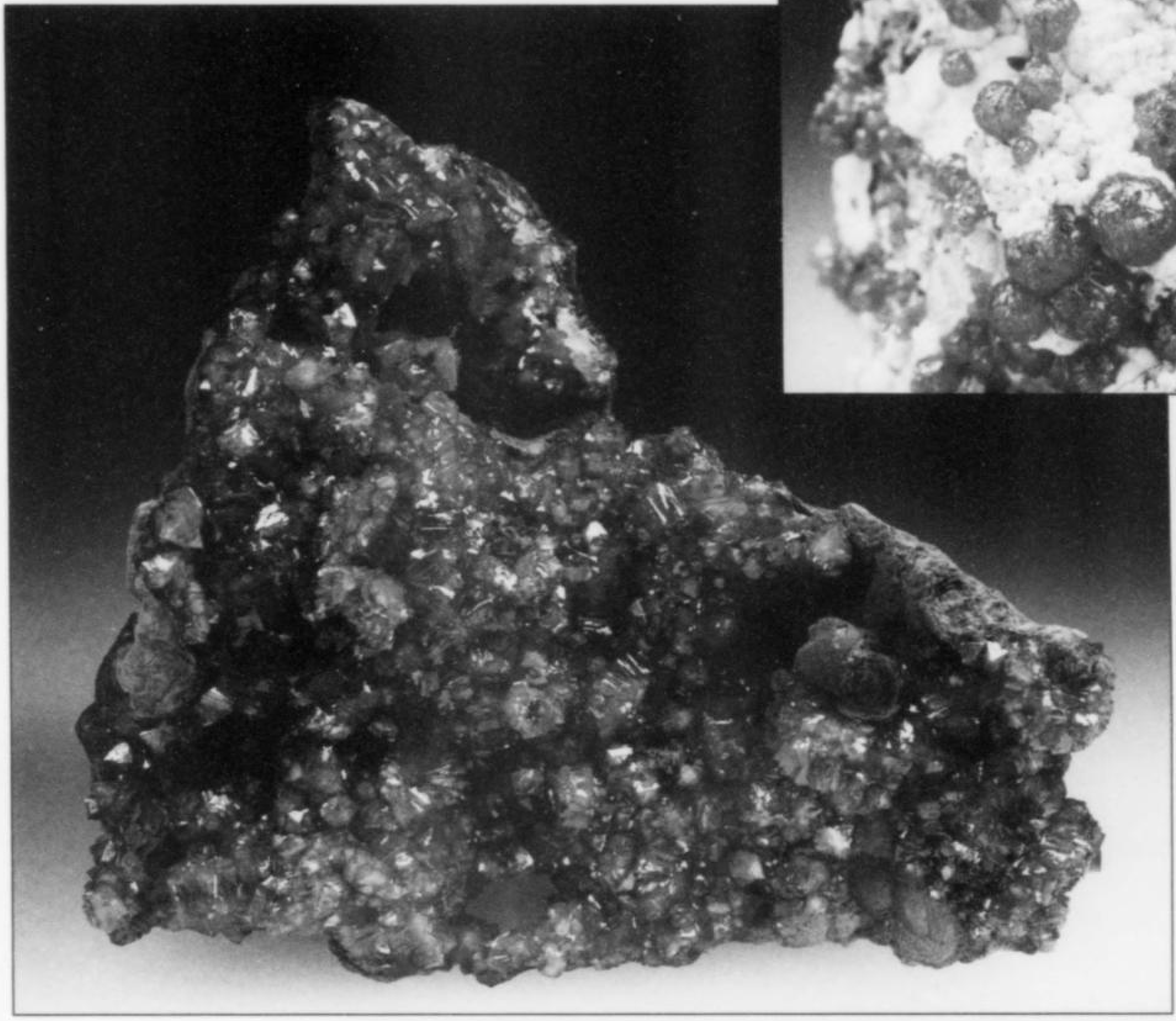
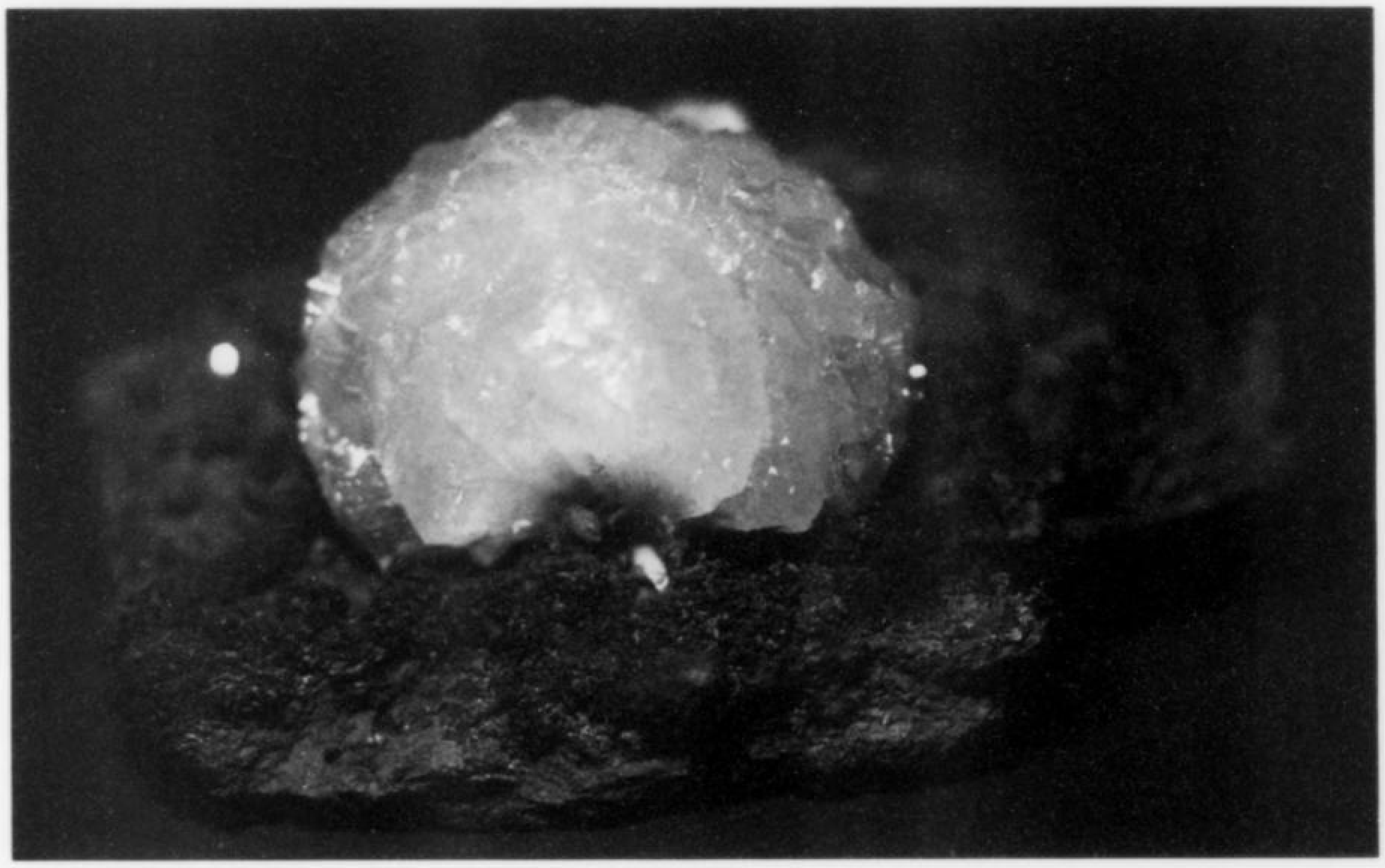


Figure 53. **Cuprian adamite sphere on limonite, 3 cm, from the Ojuela mine. Philip Gregory collection (1976); Wendell Wilson photo.**



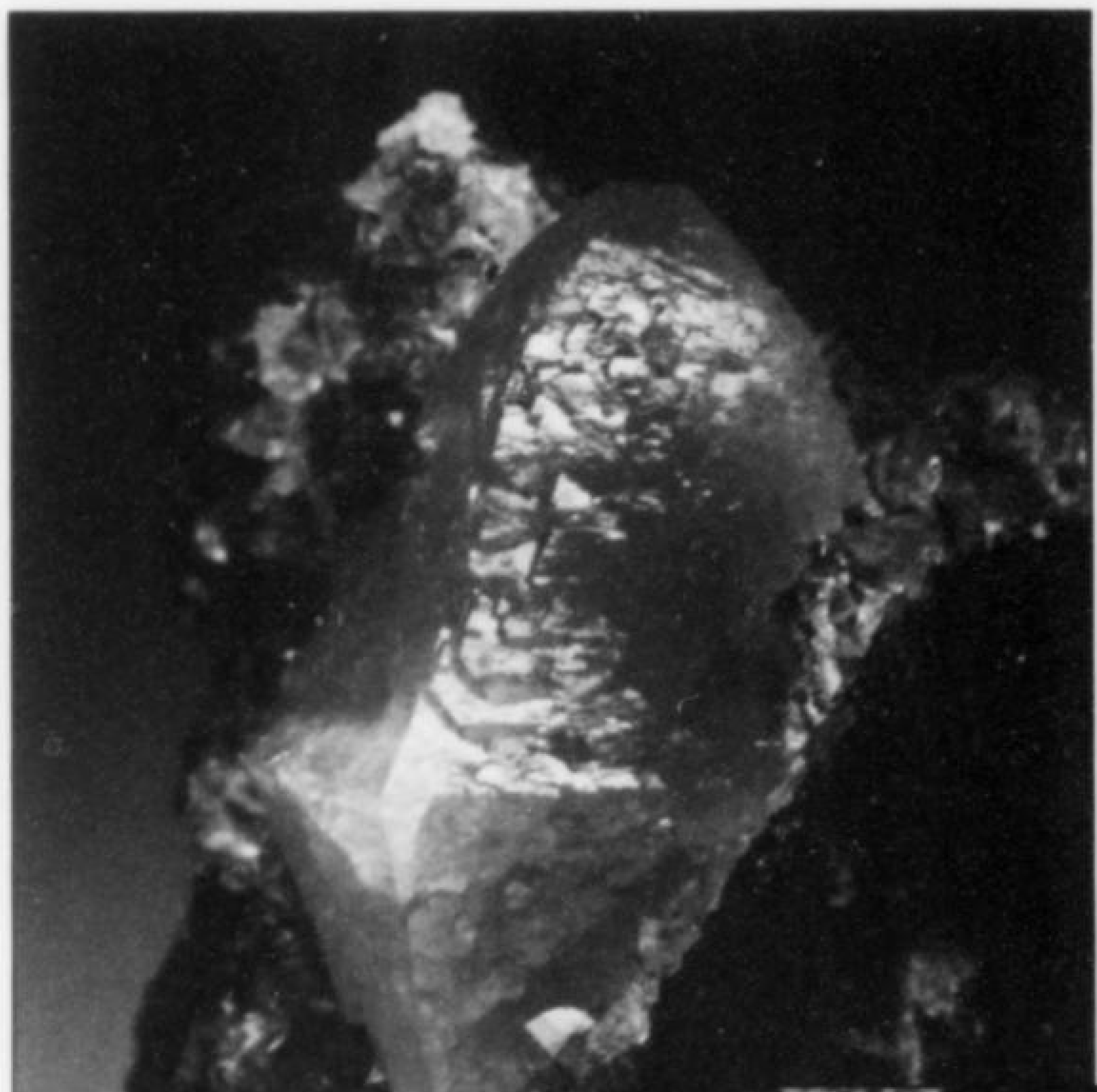


Figure 54. **Cuprian adamite crystal, 1.3 cm, from the Ojuela mine ("Number Nine" *lugar*, 1988). Galas Minerals specimen; Wendell Wilson photo.**

Figure 55. **Cuprian adamite crystal group, 2.3 cm, from the Ojuela mine ("Number Nine" *lugar*, 1988). Eric Asselborn collection; Jeff Scovil photo.**

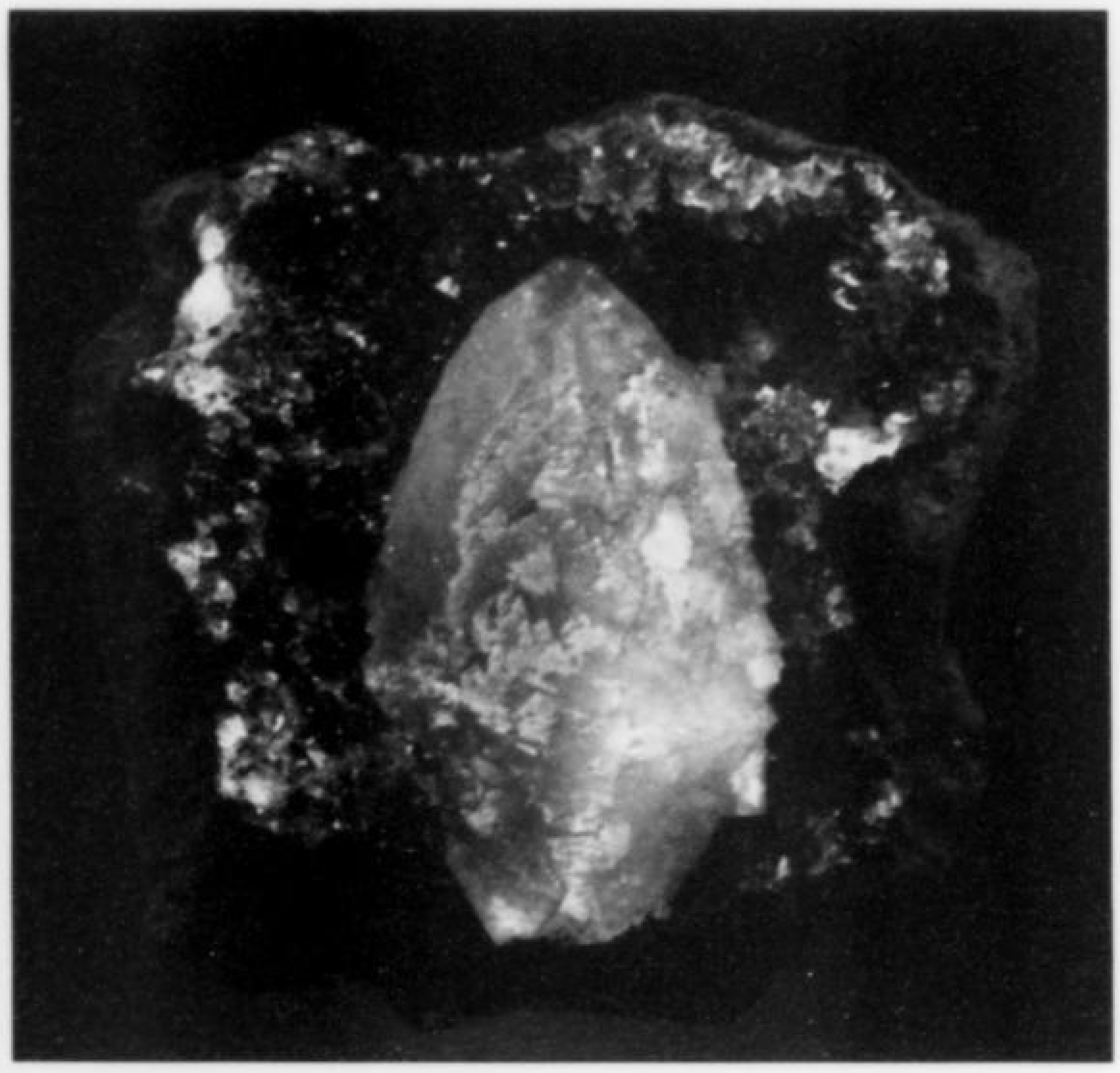


Figure 56. (above) **Cuprian adamite crystal, 2.5 cm, from the Ojuela mine ("Number Nine" *lugar*, 1988). Ron Pellar collection; Jeff Scovil photo.**

certainly settle for top-quality cabinet-sized specimens priced at the fifty-dollar figure mentioned by Jones. Market supplies of fine Ojuela adamite have inexorably declined since about 1970, despite the peak event in 1981, when the astonishing purple crystals were found.

According to Bank and Becker (1982), six faceted gemstones were cut from gemmy areas of pinkish purple Ojuela adamite crystals: the first known gemstones ever cut from this species. Later, Art Grant cut two more faceted adamite gems from rough sold to him by Mike New, and Miguel Romero bought both: a fairly clean 2-carat stone and a 5.8-carat stone with a number of internal veils.

The following is a survey of a few major adamite finds in particular *lugares*, as recalled by the miners today:

"Level Four," in the Las Palomas orebody, is still the general area which has produced some of the mine's very best adamite, including that from the 1946 grotto. Brilliant yellow and yellow-green spheres and hemispheres (wheels) to 10 cm in diameter are known.

San Juan Poniente has yielded spheres of green adamite, and blue wedge-shaped crystals to 1 cm. This zone may still contain specimens, but is currently muck-filled and inaccessible.

"Number Nine" produced bright blue adamite crystals to 2.5 cm on brick-red plates of matrix up to 20 cm across. The blue crystals perch individually on the matrix and are sometimes dusted with red where they have contacted the opposite wall of a seam or vug. These specimens were first found in 1988.

Tesoro Doce, Level 5 produced blocky bicolored yellow-purple adamite crystals to 1 cm, first found in the early 1980's, and deep purple crystals to 5 mm found sporadically until 2001. Specimens probably are still there, but the workings are muck-filled and inaccessible.

La Tolva is an area that yielded green spheres averaging 1.5 cm in diameter, exceptionally to 5 cm, on reddish matrix, in 1983/

1984. The specimen shown on the cover of Panczner's *Minerals of Mexico* (1987) is from this occurrence. The best known specimen, formerly in the Marshall Sussman collection, exhibits a doubly terminated 4-cm adamite crystal lying across a 5.5-cm wheel of yellow-green adamite.

La Cigueña has produced thick greenish yellow wheels to 5 cm in diameter, with terminations of individual crystals along the wheel edges regularly aligned, for a "cogwheel" appearance. This site was productive in 2000. Its best specimen by far, now in the collection of Bruce Oreck of Denver, is a matrix giant with 37 discrete yellow-green balls, arcs and wheels.

San Judas, Level 5 produced grayish yellow wedge-shaped crystals with murky purple areas, to 4 cm, often with tiny spheres of black manganese oxides as overgrowths, in 1974. The specimens were marketed by Willard Perkin.

San Judas, Level 6 is the area that produced the famous purple adamite find of 1981 (see sidebar). Also found here were sharp, single crystals of gemmy yellow adamite, with hemimorphite.

San Judas, Level 7 is a zone containing sharp, deep yellow to yellow-orange adamite crystals to 2 cm, grouped in flaring bundles on goethite. Specimens came out in October 2002.

San Juditas produced emerald-green adamite spheres to 1 cm, and some blue adamite, with arsendescloizite, in 1988.

La Esperanza is known for large plates of yellow adamite crystals associated with hemimorphite wheels. The association of hemimorphite with adamite is very rare in the mine: the two species, like adamite and legrandite, seem to be mutually exclusive.

Elsewhere in the Mapimí district, adamite is occasionally found as microcrystals in various small mines and prospects in the Sierra Bermejillo. Nevertheless, in view of the enormous numbers of adamite specimens taken from the Ojuela mine since 1946, it is not unreasonable to trust a label's assignment of a Mapimí district adamite to the Ojuela mine.

First Discovery of Adamite in the Ojuela Mine

The first (recorded) collecting encounter with Ojuela mine adamite took place in 1946, when Dan E. Mayers and Francis A. Wise broke into a fabulous "grotto" on Level 4 in the mine. Mayers, formerly of Tucson, Arizona and now retired in Sun Valley, Idaho, tells the story some fifty years later:

I graduated from the College of Mines with a Bachelor of Science degree in Mining Geology in the spring of 1944, and was then drafted into military service. I spent the next 20 months as a Senior Scientist at Los Alamos, making atomic bombs. On being discharged in 1946, I formed a partnership with an old buddy, Francis A. Wise, for the purpose of prospecting and mineral collecting in Mexico. We called our new company PARIMECO (Pan-American Rare Industrial Mining and Engineering Company).

We made several visits to Los Lamentos, which was at that time being run by Ing. Theodoro Holtet, a Dane with a fondness for cats. We collected large quantities of Los Lamentos wulfenites, smuggled them across the border at Ciudad Juarez, and sold them to mineral dealers and collectors.

We also visited the Ojuela mine at Mapimí, and collected there extensively. We had found nothing especially spectacular until one day a miner named Emiglio Maguelanos (who had been serving as our underground guide) pointed to a hole in the wall of the working face and shone his carbide light into it. "Como bonito! [How pretty!]," he said. We looked in and saw an entire cavern lined with bright yellow adamite crystals, of the kind people are very familiar with today, but up to that time were totally unknown at Ojuela.

We cleaned out the whole cavern, packed up the adamite specimens, and shipped them to Tucson through the Ojinaga-Presidio crossing, where the Mexican customs were in the hands of our good friends, customs brokers Albo Rios y Capitanachi and, on the Presidio side, Fred Seggerman. One superb specimen ended up going to Harvard, and is illustrated in color in a descriptive article that we (D. E. Mayers and F. A. Wise) wrote for the American Mineralogist *(1946, no. 11). Another of the best pieces went to the Smithsonian, and a third one from that original find sits in my condo here in Sun Valley.*

The adamite discovery was all the more remarkable because William Foshag, curator of minerals at the Smithsonian, had visited the Ojuela mine some years before [in 1927] *and only found a bit of scorodite and related minerals on the mine dump.* [Just below the parking area adjacent to the old miners' town of Ojuela; according to Peter Megaw (personal communication, 2003), adamite microcrystals are still collectible on this dump today—Ed.]

We at first thought we had collected all the adamite there was but, of course, the mine has continued to produce specimens intermittently throughout the years since then (to the enormous satisfaction of the miners, who quickly discovered that mining adamite for collectors was far more profitable than mining lead and silver for the smelter).

A account of the "cavern" or "grotto," was also written by Mayers and Wise shortly after the discovery, and was quoted by Mrose (1948):

Enroute to a stope containing fine specimens of wulfenite and green mimetite, our lamps fell upon a pocket in the limestone. We saw a miniature grotto, some four feet in diameter and as many deep, its interior carved into fantastic shapes and the entire surface covered with smoothly undulating waves of sparkling yellow crystals; it was a glorious sight, as though we were gazing upon a mineral specimen of unimaginable splendor . . . we set miners to work immediately and obtained some extraordinary specimens. The largest weighed 75 pounds . . . and was almost 3 feet square; it exhibited a continuous crust of green crystals about $^1/_2$ *inch in size resting on a matrix of brown limonite. This specimen, after being trimmed in shape, now rests in the U.S. National Museum. Two other notable specimens are contained in the Harvard collection.*

Purple Adamite Tales

Perhaps the most mineralogically interesting of the many ore chimneys of the Ojuela mine is the one known as the San Judas: an inclined, cylindrical body averaging about 3 x 5 meters in elliptical cross section, extending from the surface to indefinite depths below the water table. The chimney is zoned concentrically, the relative thicknesses of the "rings" varying somewhat from horizon to horizon . The outermost ring is mostly empty space, an extended barren "pocket" with skeletal networks of oxidized ore connecting it to the chimney's interior portions. Next comes a region filled with the typical earthy brown goethite gossan of the Ojuela mine; in some parts of the San Judas chimney this gossan is extremely soft, almost fluffy, such that it can be dug and scooped out by a miner's bare hands. The next ring is composed of hard, black manganese oxides; it is in vugs in this layer that the crystals of the rare arsenate species, including purple adamite, form. The chimney's core zone consists of corroded but largely unaltered sulfides dominated by arsenopyrite.

In 1981 John Whitmire made arrangements for a new group, known collectively as Artrox Minerals, to mine once again for specimens at Ojuela. He sent his wife, Rosa (a Mexican herself) down to Ojuela to close the deal and get the contract signed. The major partners in the new company were John Whitmire, Ed Swoboda and Perkins Sams. Another dealer, Delma Perry, also became involved. What followed, later in the same year, was certainly one of the most intriguing and convoluted collecting sagas ever to involve world-class mineral specimens. Below, the story is told from the perspectives of Ed Swoboda and Mike New.

Ed Swoboda's story:

My first trip to Mapimi in the early 1970's was, of course, fascinating, and I spent some time underground at the important collecting sites within the Ojuela mine. Nothing came from that trip. However, around 1980 I was working with the Texas mineral collector and oil man Perkins Sams, investigating possible specimen-mining ventures in Brazil and elsewhere. He had become involved as an investor in a new project at the Ojuela mine being organized by John Whitmire and Mike New, and in 1981 he asked me to make a reconnaissance visit to the mine and scope it out for specimen-mining possibilities.

After obtaining permission for a visit from the Mexican mine owners, I traveled to Ojuela and spent seven hours underground with a geologist's Brunton compass and a makeshift plane table, accompanied by a local miner who had an intimate knowledge of where the great specimens that the mine was so renowned for had been collected. Our underground journey focused primarily on the arsenic-rich orebodies, first to determine if the specimen miners had left any areas that could still be successfully mined, and second to devise, if possible, a work plan to mine several promising sites simultaneously, creating a sort of portfolio of digs within the mine.

Three major underground occurrences captured my attention that day. One was the legrandite location, where this rare zinc arsenate was found in glistening, flaxen to bright canary-yellow bundles of radiating straw-like crystals two inches in length and larger, in cavities in a limonitic matrix. Then there was an adamite site that had recently produced unusually large, inch-sized and over, elongated, purple-tinted pastel prisms. Lastly was the original, most prolific site of the most widely known specimen adamites from the Ojuela, the beautiful groups of bright yellow-green terminated crystals, growing side by side and coating large areas of the pocket matrix.

After we had seen these three working areas, my guide took me through a labyrinth of tunnels and steep inclines to a major haulage tunnel at a lower level that led for some 5 kilometers to the sump of a crudely excavated shaft, which opened onto the surface 700 feet above. The haulageway was at that time being used by the local miners' cooperative in their mining of argentiferous galena. To rehabilitate the old shaft, they had rigged up a primitive open skip that dangled and swayed from a rusty, frayed cable, long ago out of borrowed time. This cable, connected to a dilapidated winch topside, was able to lower and raise six miners at a time.

Passing through an area being actively mined by the cooperative, my companion and I stepped aside several times on the steep trail to allow profusely sweating ore carriers, dressed in simple, grimy loincloths, to maintain their panting rhythm of ascent, lifting incredible weights of ore up the rocky underground pathways. Certain of these carriers enjoyed local fame, having carried loads well in excess of 150 pounds the several hundred yards up and over the steep trails to the mule dock.

The several teams of mules employed in ore drayage had not seen the light of day for several years. Their food stalls, within the maze of underground rooms, tunnels and adits adjacent to the shaft, would have been choked solid with mule dung many years earlier, were it not for the rats. There were many thousands of these huge, well-fed, chestnut-brown animals living in the catacomb-like recesses of the surrounding workings. For the most part, they were passive and subdued, remaining out of sight until mealtime. However, as the sound of an incoming ore car reached the stables, the restive hordes of rodents would begin squeaking and rustling about in anticipation of the ensuing warm meal. While the muleskinners unharnessed their animals, waves of rats would begin to pour into the stable area, avoiding a small area around each stableman, who, they had grown to know, meant them no harm.

For a short time I remained immobile in the dark, in the path of their movement. They gradually overcome their caution, the nearest rats pressing within inches of my feet. I turned on my light, and the sudden beam stabbing into their ranks frightened the closer passing animals. Constantly on the move, they regrouped at a safer distance, momentarily piling on top of each other in confusion. The warm mounds of ordure eroded slowly to ground level with the gnashing of thousands of incisors. The rats which had eaten their fill turned to scuffle back through the still oncoming tide of their unfed brothers.

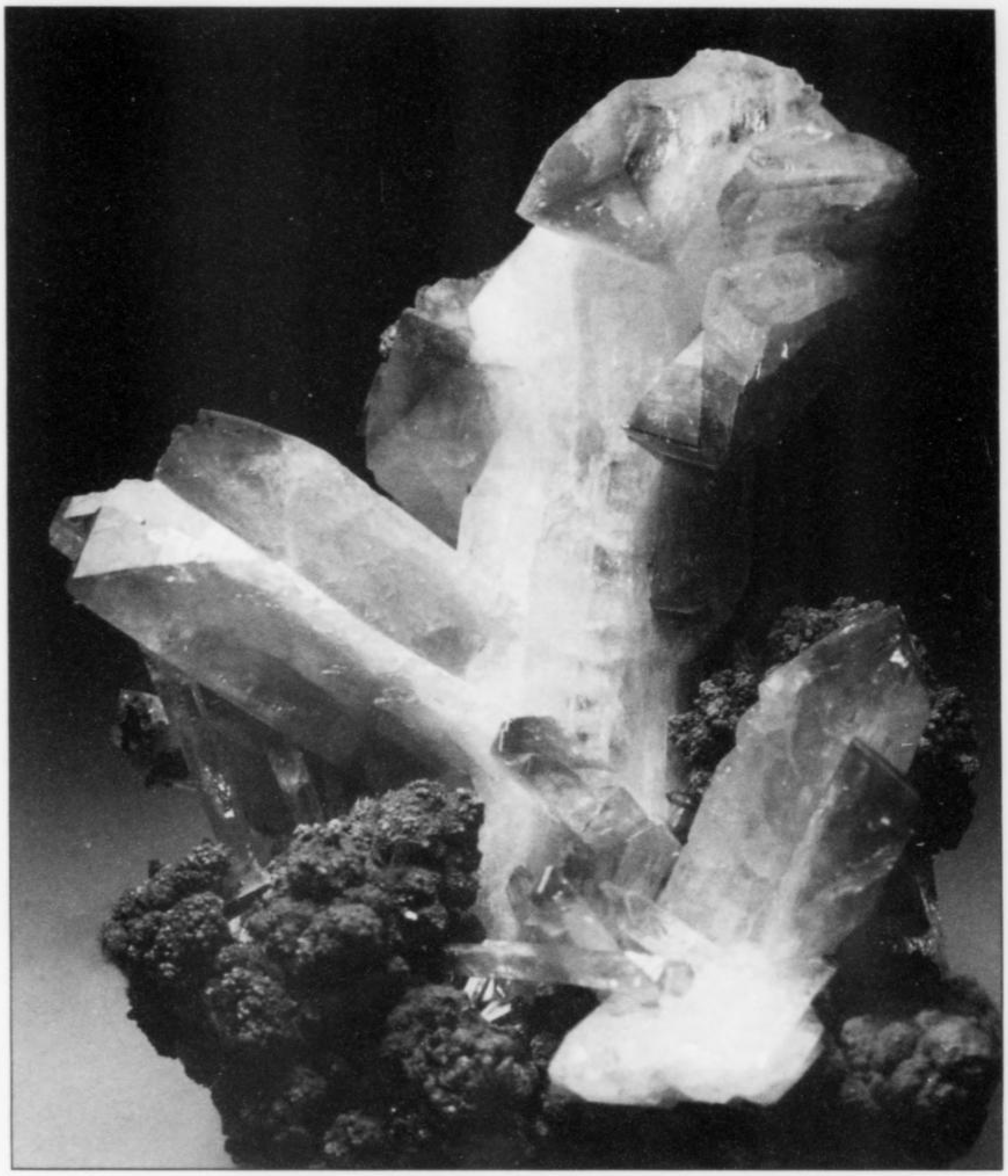


Figure 57. **Pale yellow adamite with purple terminations, 7.9 cm, from the Ojuela mine, San Judas chimney. Artrox specimen (1981), now in the Carnegie Museum of Natural History collection; Wendell Wilson photo.**

Of the three mineralized localities I visited, the legrandite site was the deepest in the old mine, situated some 700 feet below the surface. It had suffered innumerable inundations over the years from periods of rising groundwaters. George Griffith, an American dealer living in Mexico, told me that many years previously he had found his best two crystallized legrandites here, at arm's length underwater. These two specimens, each now prominently displayed in a world-famous collection, are considered by mineral cognoscente to be among the best legrandites ever found.

At the time of my visit, the watertable was unusually low, thanks in part to a large agro-pumping operation a few miles distant that was slowly sucking up the groundwater from under the entire drought-ridden valley. The legrandite location was easily accessible in a dusty, rubble-filled gallery just to one side of a main haulage tunnel.

In the maze of underground workings of this huge mine, the Brunton compass revealed to me some interesting information. Several tunnels and inclines leading to the three selected mineral sites were connected by manways—steep, twisting, narrow, squirrel-hole workings that had been hand-dug between the major levels. I began to envision a plan whereby one diesel compressor, set up at a key location beside the mule haulage tunnel, could supply air pressure for drills at all three sites, at distances of no more than 350 feet from the compressor. The hose or pipes could be routed through the convenient maze of manways and interconnecting stopes.

Fortunately, natural ventilation provided a continuous draft of cool air through the workings. In recent years, I've been told, this natural air flow has conveniently expelled the scrubbed exhaust from underground diesel-powered equipment, completely alleviating any health problems. The easiest way for a compressor to be brought down to this underground site was by lowering it by skip down the little haulage shaft being used by the cooperative. It would have to be broken down into three or four sections, lowered

Figure 58. **Purple adamite cluster, 4.8 cm, from the Ojuela mine, San Judas chimney. Artrox specimen (1981), now in the Kerith Graeber collection; Jeff Scovil photo.**

Figure 59. **Cluster of purple adamite crystals to 2 cm from the San Judas chimney. Artrox specimen (1981); Wendell Wilson photo.**

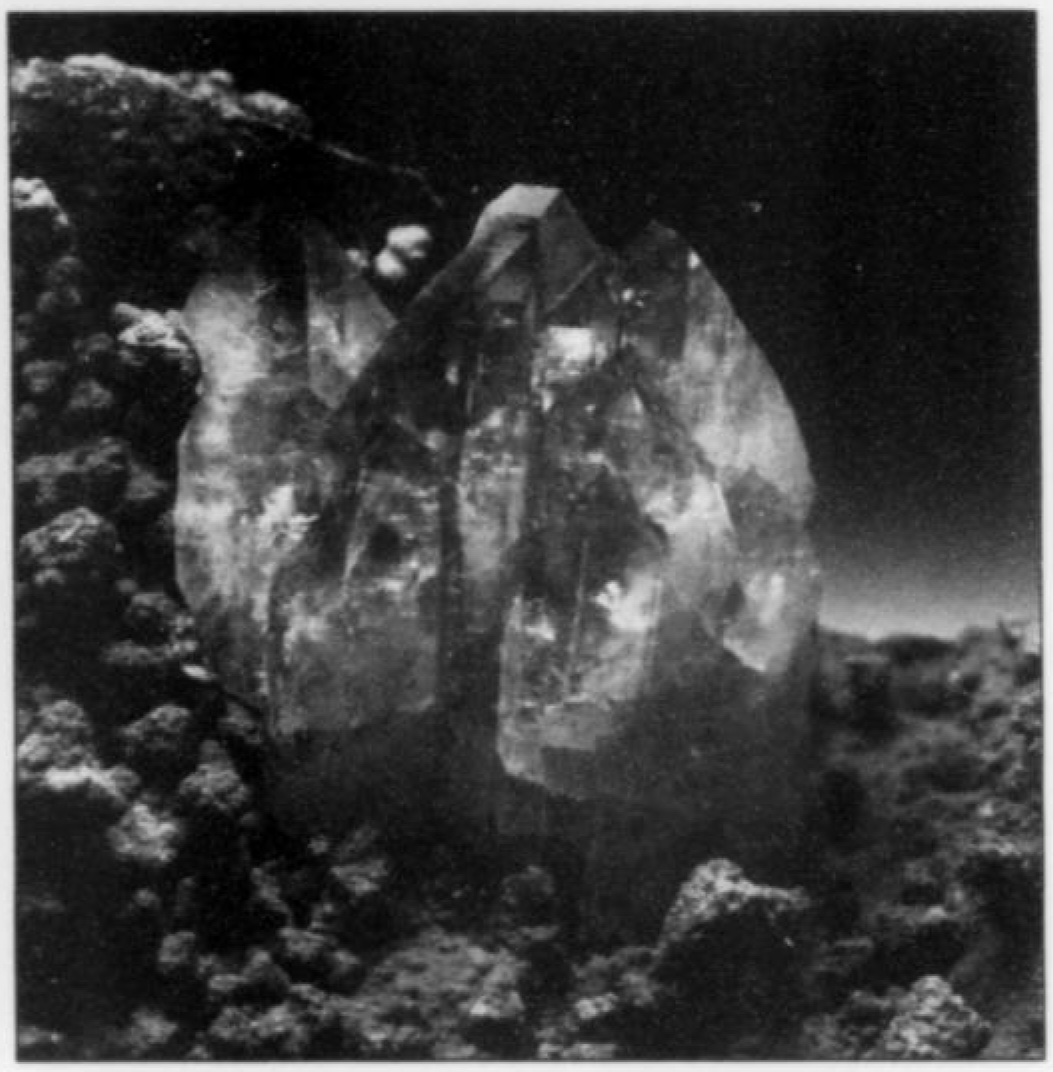


Figure 60. **Purple adamite crystals on limonite, 1.8 cm, from the San Judas chimney. Artrox specimen (1981); Wendell Wilson photo.**

separately and then reassembled in the rat gallery, to then be hauled by mule-power for 3 miles down the tunnel to its working site.

The head of the miners' cooperative obligingly gave me permission to use the shaft and haulage tunnel for the purpose I had in mind. In exchange, I offered to make available to his miners any metal-bearing ore we happened to uncover in the course of mining for crystal specimens. It was a good plan, although in the end we could not put it into operation as I had envisioned. Nevertheless, my report to Sams was very positive—the Ojuela mine clearly had tremendous potential to produce great mineral specimens!

The project then moved forward, and I followed developments at Ojuela with great interest. Work permits were granted to mine the underground, and then materials, equipment and personnel began arriving in Mapimi, where a mine office/workroom was found that served the needs of the little mining operation. Waiting for the compressor (which never arrived), Mike New, our mine foreman, put two or three of the local miners we had hired to work hand-digging at the adamite site that had not too long before produced the inch-sized pastel-tinted crystals.

After a few days of hand-digging, our miners uncovered a small vein carrying encouraging amounts of adamite. After more digging, this area looked so promising that Mike decided to place one of our miners at the site full-time. His cot practically lay astride the workings.

By this time, all of Mapimi was being updated daily on the progress of our dig. A few local people who had long been accustomed to calling the Ojuela their personal collect-

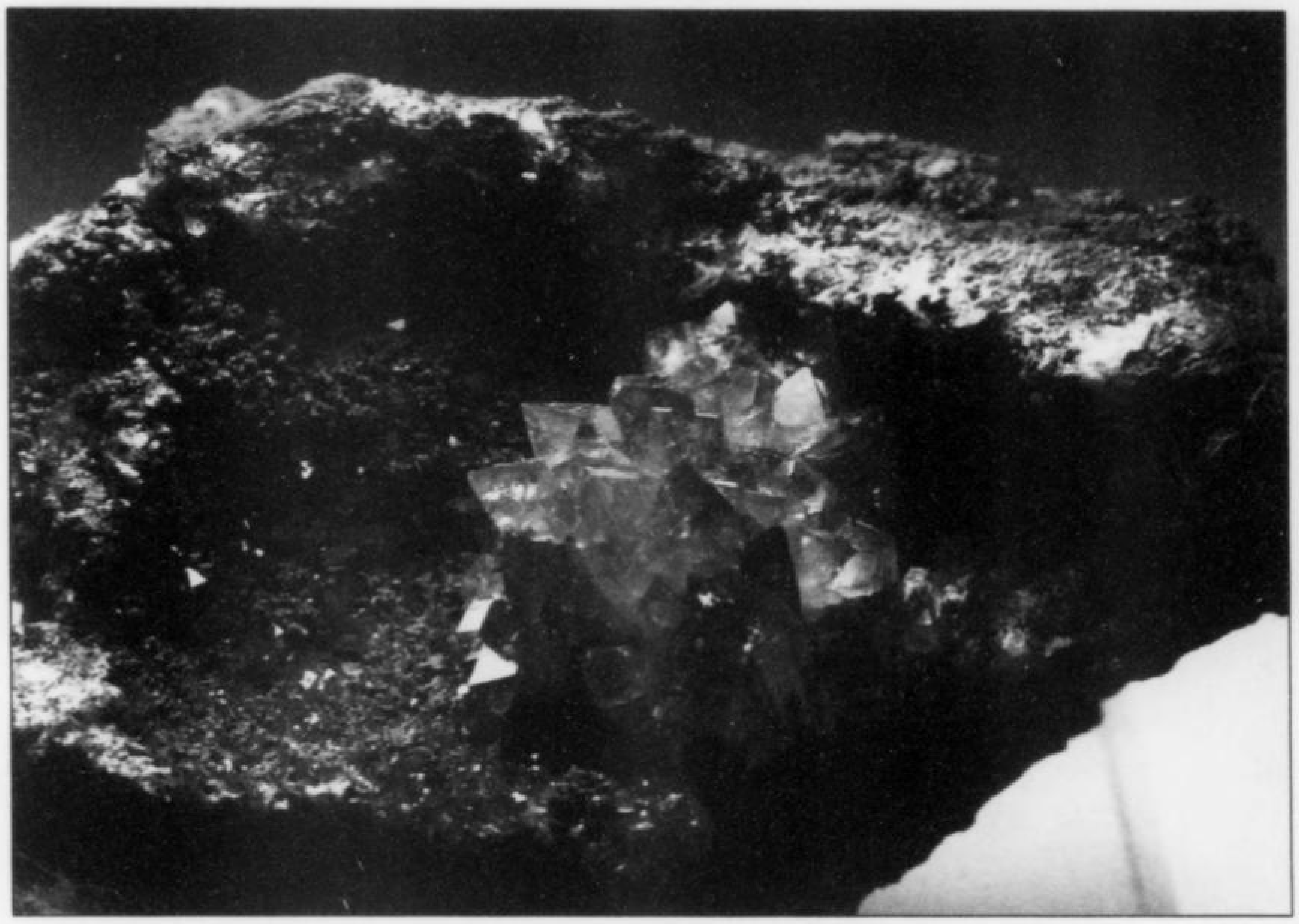


Figure 61. **Purple adamite crystal cluster, 2.6 cm, on hematitic matrix, from the Ojuela mine, San Judas chimney. Artrox specimen (1981); Wendell Wilson photo.**

ing territory decided that it was their sovereign right to protect the source of their livelihood. They developed a strategy for gaining a piece of the action, and carried it out very professionally. And their timing, as it happened, was remarkably fortunate (for them).

Awaiting an appropriate hour to visit the underground site when the guard would be alone, they paid him a visit. Knowing something of the mores of this rural Latin community, I can clearly envision this visit. It probably began with a "chance" casual meeting at the site, the visitors perhaps including one or more relatives of the guard, and the guard probably owing them for some past favor. Salutations and friendly banter would be exchanged, then a nip or two of bacanora or tequila (both potent agave-related distillates). Then more florid conversation and the heavier plying of liquor. While one member of the group completed the sousing of the guard and gently laid him on the cot, the others began to attack the now unguarded working face in which was exposed the widening vein of adamite.

As the guard gurgled and snoozed, the miners efficiently extended the workings along the vein, and in a short time (as luck would have it) they broke through into a magnificent pocket of the largest and most beautiful violet to purple adamite crystals ever uncovered! Fortunately the men were skilled in specimen removal and, to their credit, they did at least as good a job of extracting the specimens undamaged as our people could have done.

On the second day after installing the underground guard, Mike went underground to the digging area, only to find out to his complete dismay that a pocket of adamite crystals had indeed been discovered but had been completely removed by outsiders the day before! Glowing details of the unusual beauty of the crystal specimens began to circulate throughout the mining community. The more Mike learned of this well-planned rural hijacking, the more he became incensed. From gossip now being freely traded, he learned who had done the job, how it had been accomplished and, more importantly, where the crystal specimens were being held.

After verifying our legal rights in Mexico, Mike forthwith knocked on the door of the chief of the highgraders in Mapimi and threatened him with jail if he did not enter immediately into some agreement for the return of the specimens. To placate all concerned, we agreed to buy back our own crystal specimens for a substantial amount of money. In this manner we avoided legal entanglements, allowing the highgraders to save face and receive some profit from the find. We in turn made it very clear that we knew of each of the important pieces and that we wanted all of them returned. Payment was made, and all were returned safely into our hands in pristine condition, which resolved the matter sans lawsuit.

Shortly thereafter, 30 or so of the very best of these outstanding crystal groups were entered in an island display case at the annual gem and mineral show in Tucson, creating an epidemic of palpitating hearts among the visiting museum curators of the world and collectors in general. No one had ever seen such fabulous adamites as these smooth, transparent clusters of intergrown prisms, terminated and lustrous of face, in unique shades of rose-violet to purple.

Mike New's story:

During the late 1970's, Curt Van Scriver and John Whitmire (both now deceased) were running a project to extract adamite from the Ojuela mine. I was asked to come down and assist Curt in getting started. I wasn't sure how I could help, as I had no Spanish at the time, but go I did, and made then my first acquaintance with the mine.

Curt and John had been working (without any official

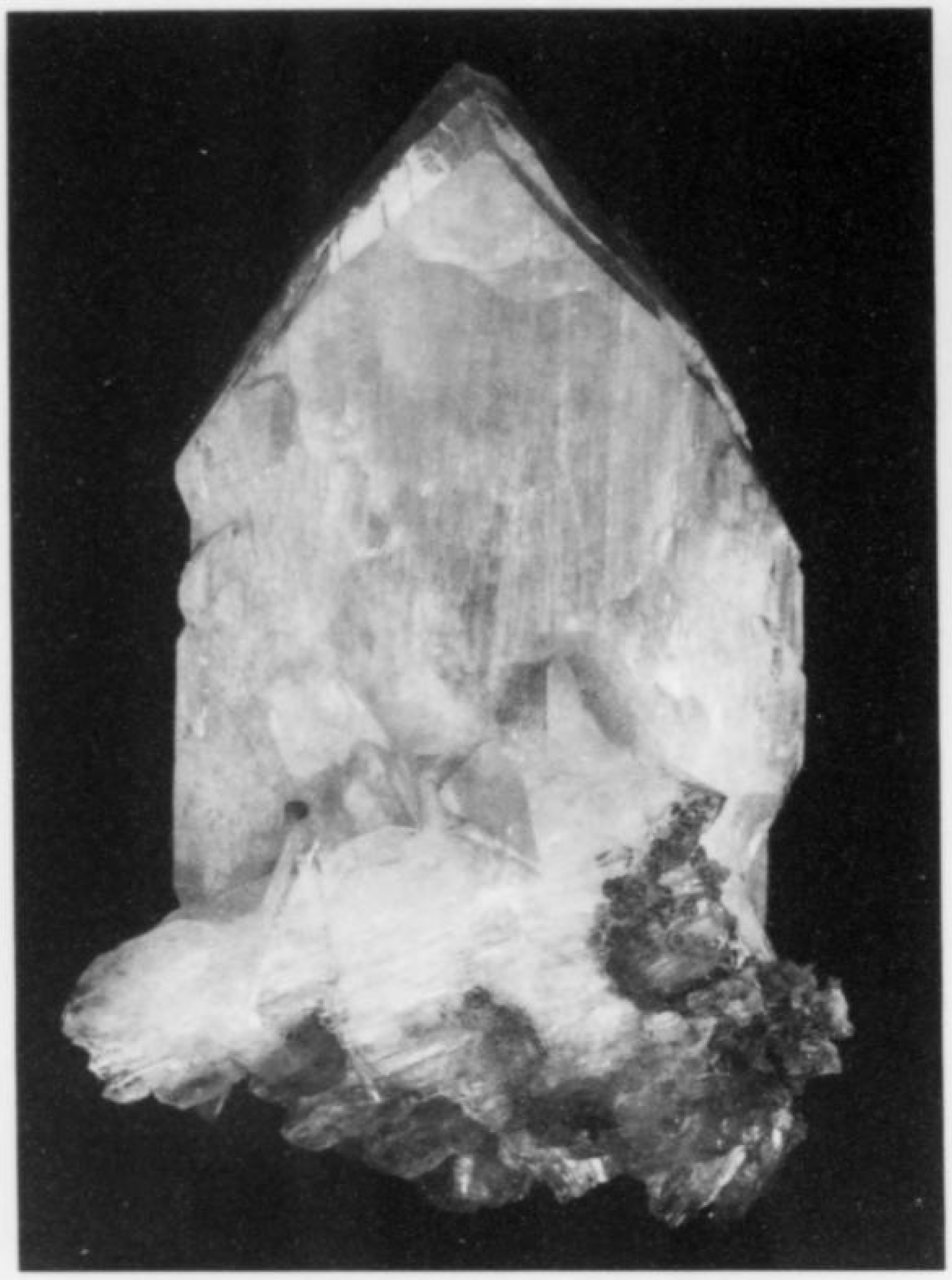


Figure 62. **Large, 5.5-cm, crystal of pale green and pale purple adamite from the Ojuela mine, San Judas chimney. Artrox specimen (1981), Kerith Graeber collection; Jeff Scovil photo.**

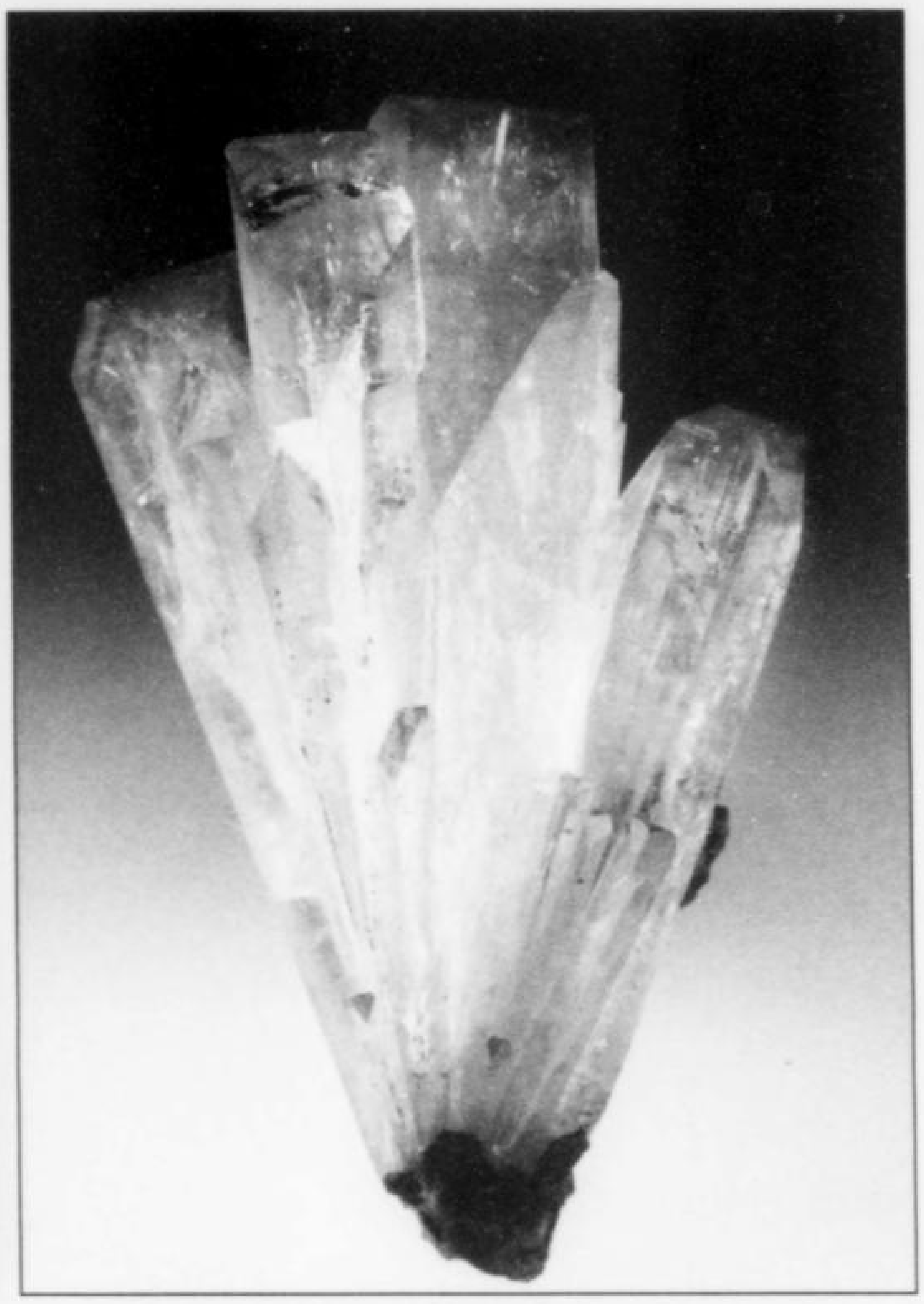


Figure 63. **Cluster of purple-tipped, pale yellow-green adamite, 3.5 cm, from the Ojuela mine, San Judas chimney. Artrox specimen (1981), now in the Ralph Clark collection; Wendell Wilson photo.**

status) on level four of the mine: the area that had produced so much adamite over the years. They had been collecting adamite with one crew and mucking out an adjacent stope with another. To date they had been quite successful, and had lots of adamite stockpiled in their house in Mapimi.

Of course, their success enraged the Mexican buyers, who for years had thought of Mapimi as their own private turf. John and Curt were operating on only tourist visas, and in order to stop them, a consortium of buyers, local collectors and other interested parties contacted the local immigration authorities, who politely asked the two *gringos* to leave. This consortium then bought liquor for Mateo Irigoyan of Santa Eulalia, Chihuahua, whom Curt and John had placed in charge in their absence. While Mateo was sleeping off the effects, some members of the consortium confiscated some of the material that Curt and John had collected and warehoused. They found it easy to select what to take, since Curt had marked the balls of wrapping paper which contained the high-grade specimens. Curt and John were not allowed to return until they could get their legal paperwork in order, and Curt never did get the chance to come back to Mapimi (he was killed in an auto accident in Arizona in 1982).

In late 1980, John Whitmire and I talked about reviving the project at the Ojuela mine. I said to him that I could only imagine trying it if I had legal paperwork which would protect us against problems like those experienced last time. He agreed, and I went to Mexico City to get the necessary papers—a process which, in those days, was difficult and time-consuming. During my visits to the various government offices, including *Hacienda, Relacciones Exteriores*, and *Immigracion*, I met a gentleman who happened to be in charge of *Hacienda* (the Mexican Internal Revenue Service). With his help, I was able to obtain a work permit and an FM3 visa which stated that I could move into and out of the Republic of Mexico at my discretion, and that I could export materials classified as *Patrimonia Nacional* ("National Treasures") through any of the border crossings. This was and still is the only such visa in existence; I have never mentioned publicly until now that I have it.

A Mexican company was formed, Compania Las Delfines, S.A. de C.V., whose members were Ruben Rodriguez of Mexico City, Miguel Romero (now deceased) of Tehuacan, Puebla, and John Whitmire of Yuma, Arizona, with me as operating manager at Mapimi. Eventually this group came to be known in the U.S. as the Artrox company.

In April of 1981, I started assembling various pieces of equipment in Phoenix, Arizona, where I lived at the time. It was not possible to purchase things like a 125 CFM air-cooled Atlas Copco compressor in Mexico, and I wanted to have all parts, fittings, etc. on hand before starting to mine. This was naive of me: little did I know how Mexico worked.

In June of that year, I left hearth and home to begin the adventure. In Mapimi, John introduced me to the men who would be working for me—even though my ability to speak Spanish was still limited to "por favor" and "gracias." We hired seven miners, two guards, and a *jefe* or *incargado* (the guy in charge below me). At this time, John informed me that we needed another partner. He wanted Edward Swoboda, but I was against it, since I didn't know how I would like working with Ed. I had about $15,000 personally to invest in the operation and John had a similar amount, so I felt that we already had enough capital and enough partners. However, John later told me that both Ed Swoboda and Perkins Sams of Midland, Texas had become involved in the project (Swoboda was at that time working for Sams, and it was probably the financial backing of Sams that John was actually after). Swoboda made a reconnaissance visit on behalf of Sams, and was favorably impressed with the possibilities.

I was introduced to several people who would turn out to be very important to our success at Ojuela. Don Santos Pargas (now deceased) was the Compania Peñoles representative who lived in Mapimi and oversaw the mine for the company. Don Eduardo Cordoba was (and has been for 45 years as of today) *presidente* of the miners' *cooperativa*, which group extracted ore from the mine and sold it to Peñoles. Don Eduardo Cordoba is now 82, and goes to the mine daily as a representative of my company, Top-Gem Minerals.

I decided that a formal undertaking such as we had planned would best be served by taking a serious look at the various areas in the mine where specimens could be found. I felt that two weeks or so would be enough time to get acquainted with the various stopes and *lugares* (work sites). I was helped in this endeavor by Jesus Cardoza and Pedro Ayala, my *jefe*. Don Lazaro de Anda, Senior provided valuable information as to where different kinds of specimens had been produced in the past.

Just before I arrived in Mapimi, several lots of a new kind of adamite had appeared on the market: large, to 4 cm, yellow-gray crystals. No one knew where this material was coming from in the mine. During our inspection of various areas, we had looked at a place on level 6 that had never before been available to collecting since it had been below the water table. The droughts that had been occurring in Mexico during this time and the increased production by wells in the area had lowered the water table sufficiently for us to be able to look at this *lugar*. The site was called level 6, San Judas Vein, and I felt that this was the source of the promising new adamite.

The place was muckbound, and we started hauling muck out of it and to an area about 400 meters away that was available for dumping waste. To haul muck, a miner, using a strap around his forehead, hoists a small metal drum filled

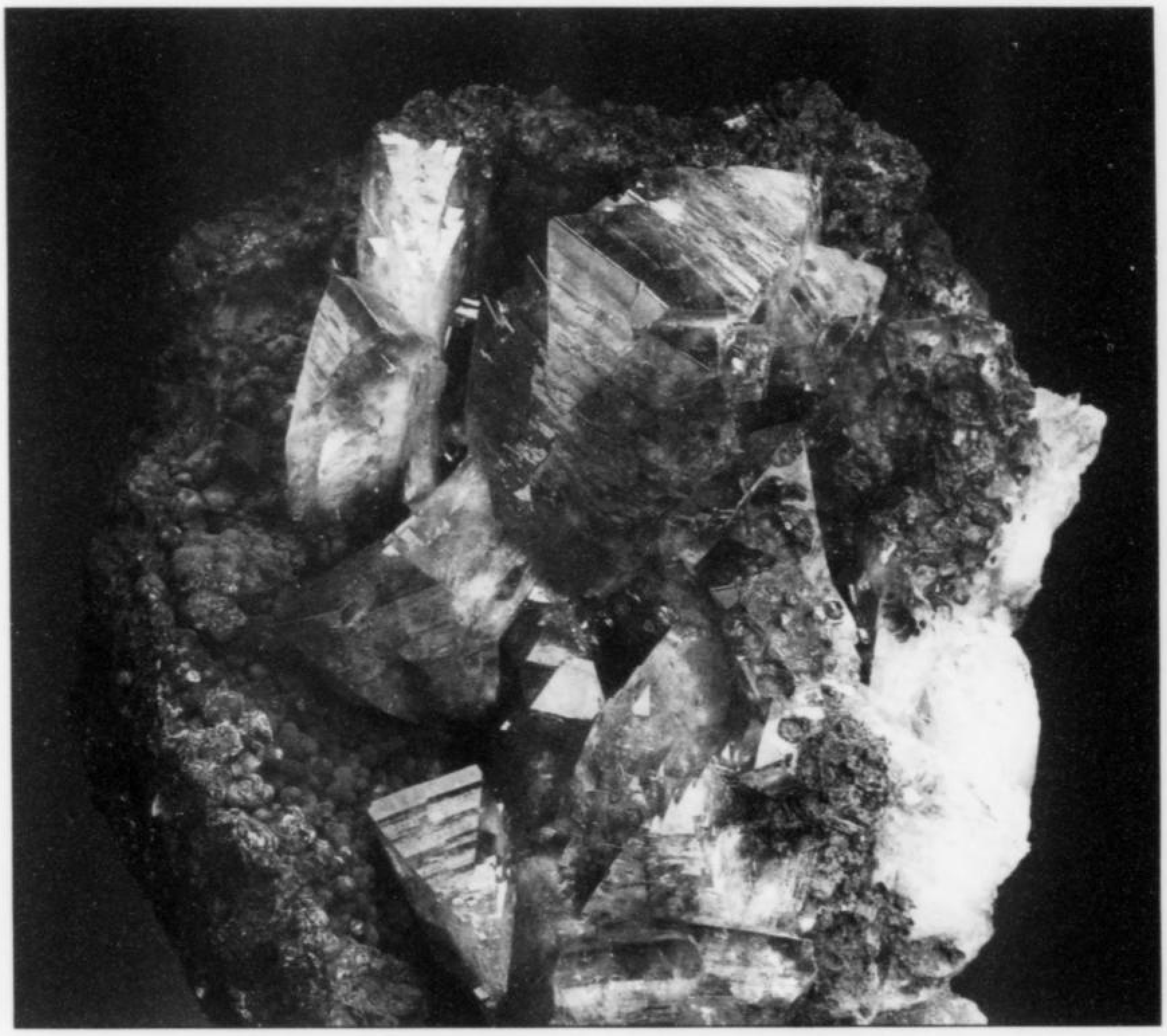


Figure 64. **Purple and pale yellow-green adamite crystals on matrix, 6.9 cm from the Ojuela mine, San Judas chimney. Artrox specimen (1981); Jeff Scovil photo.**

with muck on his back; when filled, the drum, or *bote*, weighs about 60 kilograms. Our miners would load the *botes*, climb ladders to the surface, then walk about 400 meters to dump the waste. We worked in this fashion for 19 days until we hit the first in-place *fierro* (limonite).

At this point, I think a short description of a typical day is in order. Miners would assemble at my house at 5:30 a.m. or so and we would all pile into my small Datsun pickup. None of the miners had their own vehicles. I would stop by the restaurant, *Lejano Oriente* ("Far East," owned by Antonio Carlos Fong Foster), to pick up my breakfast and lunch, which was hot and ready to go at 6:00 a.m. We would drive, approximately 8 kilometers, to a point in the big arroyo, just north of the bridge, where a tunnel entered the mine. The *cooperativa* wouldn't let us use the skip, as other miners did, purportedly because they didn't want to be responsible for a gringo's getting hurt or killed in the shaft. From the tunnel entrance—on level 2—we would walk about 1.5 kilometers on level ground, then start down the chicken ladders and cable ladders to reach level 4; from there we would climb down a large muck pile to enter level 5 near the base of Tiro Cuatro (Number 4 shaft), then proceed along level 5 for about a kilometer to a cable ladder that dropped us onto level 6; at last we covered the final 600 meters to San Judas 6. There we would cook our breakfast over an open fire with a 55-gallon drum lid as the stovetop. After breakfast it was off to work: mucking, hand drilling, etc. until 1:00 p.m., when we would eat lunch and then commence work again.

At 3:00 p.m., we would start our climb back out of the mine. For me, this climb was the final insult. My best time coming out was 53 minutes. The miners would commonly do it in 40 and could get it down to 35 if we were having some sort of contest. My losing these contests (as I always did) was the occasion for me to buy the beer.

By the time we hit the first in-place limonite, I was really getting tired of seeing muck; I had lost faith that we would ever get to collect any minerals. That day, when the miners went up to level 6 for lunch, I started to beat on rocks. I opened a small pocket of pretty good yellow adamite and decided to come up from under it to try to take out the complete pocket as one specimen. I started chiseling away limonite about 2 feet below the pocket. Suddenly my chisel sank into another pocket. I pulled out the chisel and looked in. There, sitting pristine and wonderful, was what would turn out to be the first purple adamite I ever collected. When the miners returned from lunch, this one piece seemed to bring new enthusiasm into the work. John later sold this piece, a large miniature with four 3-cm crystals on matrix, at the 1981 Detroit show. I don't know who the lucky buyer was.

In those days, in Mapimi, there were probably 30 or 40 people who collected either full or part-time, and every one of them posed a hazard. Even my own people, including the *jefe*, would have been more than happy to augment their income surreptitiously. Everyone had the buyers' telephone numbers at hand, and I knew that news of the find could not be kept quiet; the danger of theft loomed large. I decided that now would be a good time to build a seriously strong door and post guards.

We continued working the zone, finding a small pocket here and there, but nothing that would pay the bills. On October 24, 1981, my 36th birthday, we started working a very hard bit of *fierro*. Pedro was hand-drilling, and suddenly his chisel sank in full length; when he pulled it out, water gurgled out of the hole. We spent an hour or so hand-chiseling this area. Because of problems with Mexican customs, our air drills, jack legs, compressor, etc. had never shown up, so all work was by hand—and this was probably just as well. When we pulled a large piece of *fierro* away from the working face, we found ourselves staring into the prettiest pocket I had ever seen. There were about 10 specimens still attached to the walls, with adamite crystals up to 6.25 cm. The small toenail-sized specimen pictured on the cover of the *Mineralogical Record* [May/June 1982—this specimen is now in the Ralph Clark collection—*Ed.*] was lying on the floor of the pocket, just below its former point of attachment. The piece that was later sold to the Sorbonne was in the back of the pocket, and the best piece, though smaller, was lying loose on the floor. This was a miniature/small cabinet specimen with one large crystal (4.5 cm) on matrix surrounded by smaller crystals. The color zoning was similar to that of the toenail specimen: yellow-green at the base, grading to yellow-white in the middle and a wonderful magenta in the upper third. A single, very large crystal was also lying on the pocket floor. This crystal, off matrix, weighs about three quarters of a pound, and has color zoning like that of the pieces just described. I don't know who owns these specimens now, but the owners should consider themselves fortunate indeed.

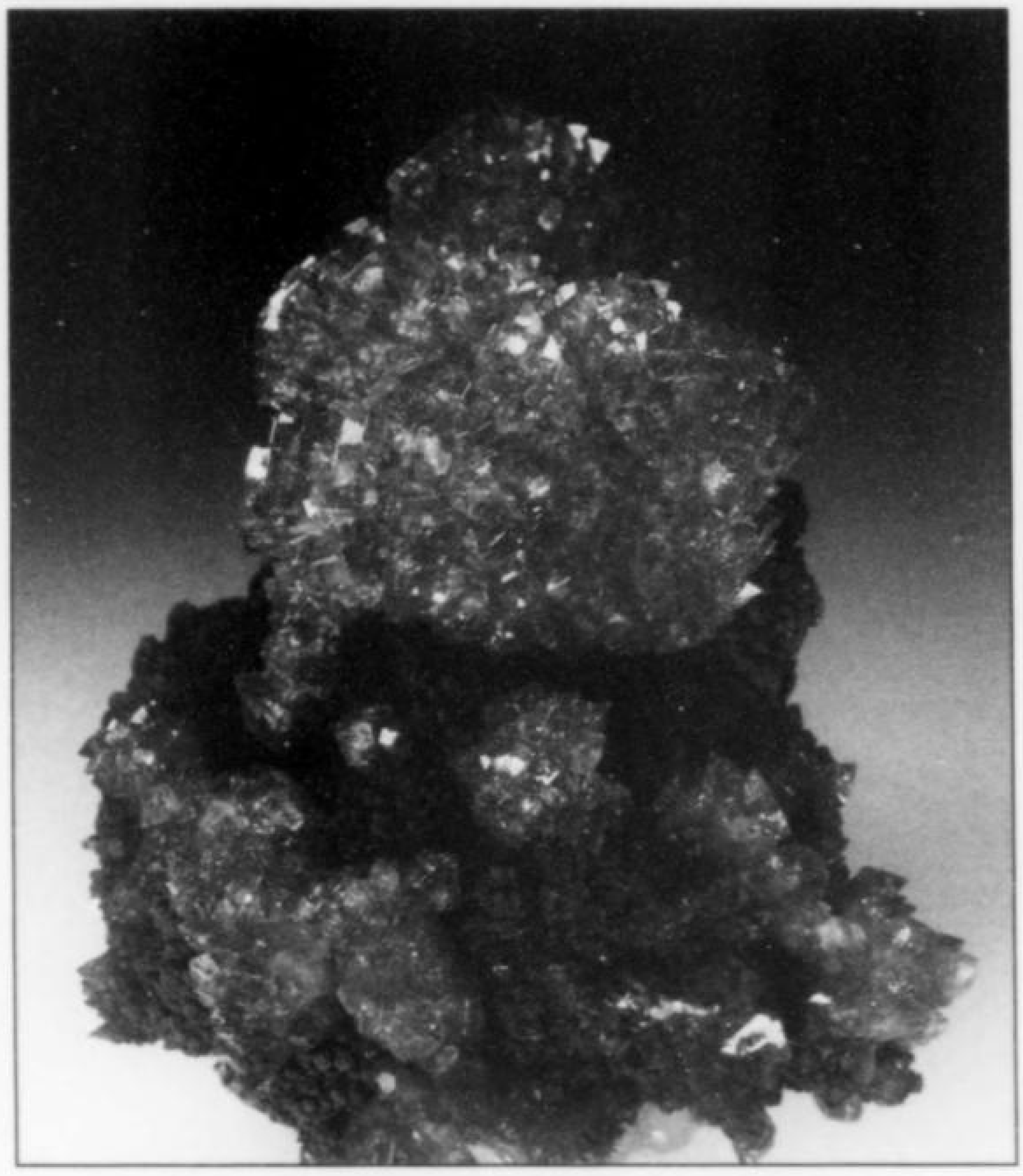


Figure 65. **Drusy clusters of purple adamite on matrix, 7 cm, from the Ojuela mine. Miguel Romero collection, now in the University of Arizona Mineral Museum; Wendell Wilson photo.**

All eight of us working that day just stopped, stared into the pocket, and spent about an hour laughing before resum-

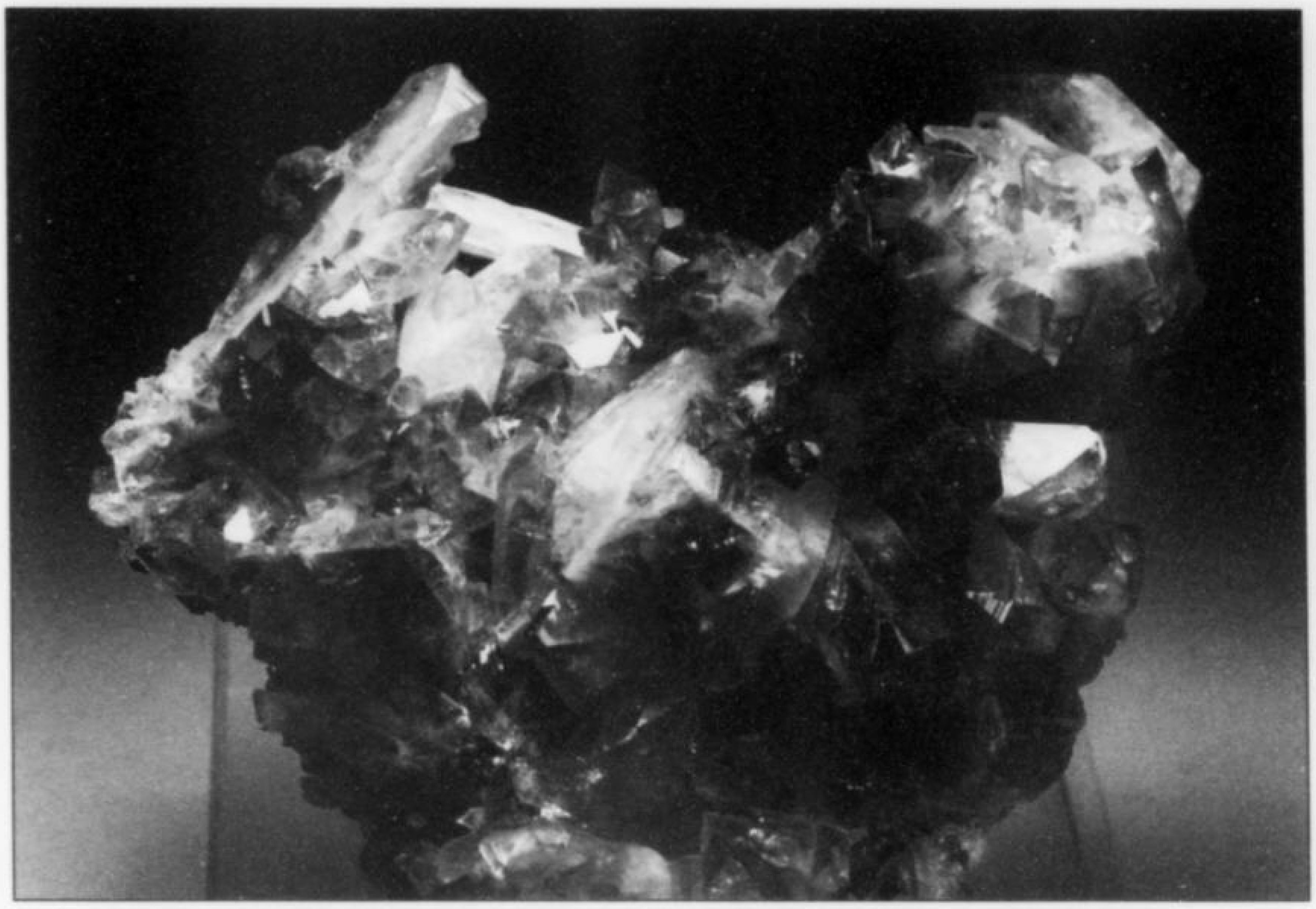


Figure 66. **Large purple adamite crystal cluster, 8.6 cm, from the Ojuela mine, San Judas chimney. Artrox specimen (1981); Wendell Wilson photo.**

ing work. We had to stay underground until the pocket was finished. We arrived home that night at about 11:30 p.m., out of cigarettes, out of water and soda, tired, and very happy. The miners got production bonuses for collecting good pieces.

Of course, this success did not go unpunished. Gossip got down to Bermejillo and to Ciudad Juarez, and everyone began trying to figure a way to get me gone. Articles were written in the newspaper in Torreon about the greedy *gringos*, plans were made to cause problems, and the fun started. A *sindicato* (union) of buyers and collectors was created, and representatives of it came to the mine entrance one day to tell me I was working illegally. I knew I had all the required paperwork, so I told them to go away. Next, they got the police in Bermejillo to come to Mapimi to try to intimidate me with some obscure investigation that the small sum of $8,000, it was said, would resolve. No luck there either. Then they presented the governor of Durango with forged paperwork testifying that I was a serious detriment to the community. A demand was placed against us, and we had to halt work until everything could be sorted out.

Miguel Romero sent his attorney from Mexico City, and I, Santos Pargas (as the legal representative of Compania Peñoles), the attorney, the mayor of Mapimi, and one of the local *Hacienda* (read: IRS) officials all presented ourselves to the governor. We had minutes from a town meeting attended by representatives of all the local businesses, representatives of the collectors, and other interested parties, who all had signed testaments to my good faith, honor and responsible actions. The same names had appeared on Salvador Davila's paperwork but the signatures seemed to be different. Our problem was quickly cleared up.

Unfortunately, during this interruption in work we were also attacked in a different, and ultimately more serious, way. One of my guards was quite fond of beer, and (as had happened with the guard employed by Curt Van Scriver and John Whitmire in the 1970's) the local collectors used this fondness to incapacitate him for the several days we were away. These collectors broke down our heavy door and took out some material. When I got back from seeing the governor in Durango City, Miguel Romero advised me that a batch of newly collected adamite specimens existed in Mapimi. Shorty Bonilla, a runner used by Bill Panczner of Tucson, was on his way to Mapimi, and Bill had asked Miguel to send money to Bonilla to buy the specimens.

I tried to think which local group might have committed the theft, and how I might get to see the material. The local collectors knew that if they were caught they could face jail time. I decided to talk with Ignacio Gonzales, one of the most avid collectors in Mapimi. I told him that I had heard someone had taken some material from my area, that the material was being offered to Bonilla, and that I too was interested in buying it. I told him that if I got the specimens, no one would go to jail, but that if I didn't, life in Mapimi would be miserable for those responsible; they would indeed do jail time. He told me that he would investigate and let me know within the hour. This talk took place in his home, in his front room, probably not more than 20 feet from where, I was pretty sure, the specimens were—under the bed.

Within the hour, good as his word, Ignacio presented himself to me, telling me that he was acting as agent for the people who had the adamites and had full authority to conduct business on their behalf. We returned together to his house, and he pulled several boxes out from under the bed. The quality of the adamites in these two flats probably has never been equaled in Mapimi, before or since. There were

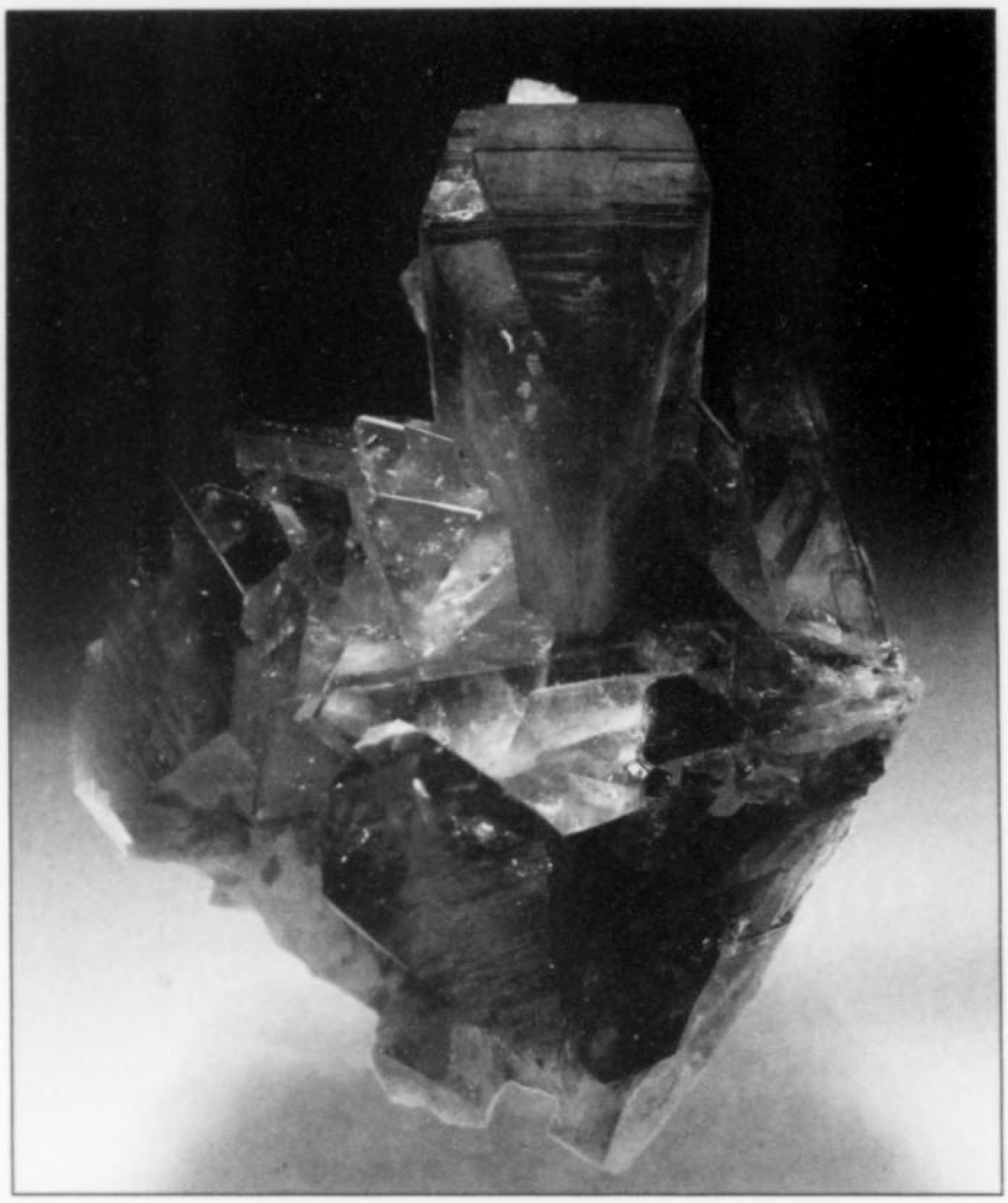


Figure 67. **Miniature-size purple adamite crystal cluster, 4.3 cm, from the Ojuela mine, San Judas chimney. Artrox specimen (1981); Wendell Wilson photo.**

26 specimens, from miniatures to small cabinets, with crystal sizes to 4 cm; the color was an intense purple. Three of these specimens would end up in the Perkins Sams collection, now at the Houston Museum of Natural Science. A price was agreed upon, a deal struck, and then I casually said, "Of course, you will have to wait for your money because I don't keep $8,000 here in Mapimi." He was OK with that, but wanted to maintain possession of the goods until payment was made.

I knew that quick action was required: Ignacio might sell the pieces to any other buyer who showed up with a better offer. I called John Whitmire, but he wasn't home. Then I called Miguel Romero in Tehuacan, who offered the $8,000 to me personally to buy the material for him and me. I told him I couldn't do that, and, reconsidering, he agreed that the group as a whole should benefit. Next I called Swoboda at home; coincidentally, Whitmire was there also. I told them about the lot and the deal I had struck with Ignacio. John reacted pragmatically; Swoboda at first tried to lay the blame for the theft of the specimens on me, but finally understood that we had been legally barred, at the time, from entering the mine. Ed asked me if I thought the lot was worth the $8,000 I had agreed to pay, and I said, "I will mortgage my home to get this lot . . . If you don't want to buy back the stolen pieces, that's OK with me." I knew Miguel had the money but still felt that the lot rightfully belonged to the Artrox group.

Ed and John agreed that John would come down to Mapimi with Perkins Sams' personal representative, Ron Bentley: they would arrive in two or three days with the funds. In the meantime, needless to say, I was on pins and needles. Curt van Scriver had heard about the lot, and called me to find out if I had it under control. Bonilla was on the way from Chihuahua City as soon as Panczner could scrape up the money.

Ron and John made it to Mapimi in time, and viewed the lot. Before they did so I was careful to tell Ron *not* to make any comments when he saw the specimens, as the price could still change. We did the deal, Ron and John left with the adamites, and I went back to work collecting. Most of the specimens were sold during the following Tucson Show (1982), and some *individual* pieces brought more than $8,000 retail; the best specimens from that lot would bring vastly more than that today.

As a side note, Ignacio told me years later that when he broke into the *lugar* to collect that night, he sat down at one point on a ledge of *fierro* facing the area where we had been working. He moved a rock to get more comfortable and noticed a piece of tissue stuck in a small hole. He pulled out the tissue and the small hole turned into a pocket of adamite; some pieces had already been collected and some were still attached to the walls. He guessed that my own people had found this pocket and had decided that they would come back at night and help themselves to a nice bit of change. Unfortunately for them, we got the demand against us on the same day they had planned to go back in, and even these guys were afraid of the consequences of being found on mine property until the demand had been lifted.

In the months following this episode of discovery/theft/ recovery, I continued to work San Judas, finding more purple adamite and a host of rare minerals, some of which were new to science—lotharmeyerite, villyaellenite, scorodite, köttigite, ogdensburgite. During this same period we also worked several other areas—America Poniente, Los Chongos, Plan de Ayala—in a futile search for legrandite. The only thing of note that we found was one specimen with very small crystals of tsumcorite; Miguel, to whom I sent the specimen, later told me the identity of this mineral, but the specimen has since been lost or is still unavailable in storage.

I did locate a good zone for wulfenite/mimetite in La Campana, but this *lugar* was so far (3 km) from our other areas that I decided to have some of the local *risceros* work the zone with a promise on my part to buy what they collected. About a week later, they showed up at my house on a Sunday morning with about 30 kilos of material including the finest wulfenite that Mapimi has ever produced. The crystals are thick, of a good orange color, up to 4.5 cm, and sit on bright green mimetite. Kerith Graeber, who owns one of these pieces, said she had never seen such clashing colors on a mineral specimen.

When we all assembled at the Tucson Show in 1982, the financial bloodbath began. I had spent about $19,000 to that point in producing all of the purple adamite. During this same period, between John, Ed, and Perkins Sams, another $80,000 had been spent. Additionally, I had used my own funds for part of the expenses, and I had not been paid my monthly salary due from the Artrox group; I was also supposed to get a 10% commission on all sales. In due course my monthly salary was paid, but I never got the commission monies. Finally I decided that I really didn't need this group's help, and could just as well work the Ojuela mine with only Whitmire as a partner. And that's what happened.

Under this new regime the work continued at San Judas. We produced more good purple adamites, and we produced other materials from other areas. By April 1983, we had worked San Judas to such a depth that we again encountered the water table. During the last three weeks of the project we were working in water up to our waists, and finally decided to stop. We were still in good ground but the water problem was insurmountable. I had stacked about 300 tons of muck behind some cribbing which we had placed about 12 meters above our final depth, and this muck included about 2 tons of lotharmeyerite-rich specimens. No one seemed very interested in that species at the time, so, when I pulled the cribbing, 2 tons of lotharmeyerite, along with 298 tons of waste, went down as fill in our zone. I hoped that the water would someday be low enough to permit us again to work the zone, but in the meantime, I felt, the lotharmeyerite was well protected.

In 1996, as representative of Top-Gem Minerals, Inc., of Tucson, Arizona, I again arranged a collecting contract with Peñoles and with the *cooperativa*. It continues in force today.

As both writers mention above, the San Judas purple adamite specimens made their debut at the 1982 Tucson Show. Every one was exceptional (Wilson, 1982a, 1982b), with the best cabinet specimen being priced at well over $10,000. One of the top pieces was purchased in 1993 by John Barlow: it is the 4 x 5.5 x 7-cm group pictured on p. 336 of *The F. John Barlow Mineral Collection*.

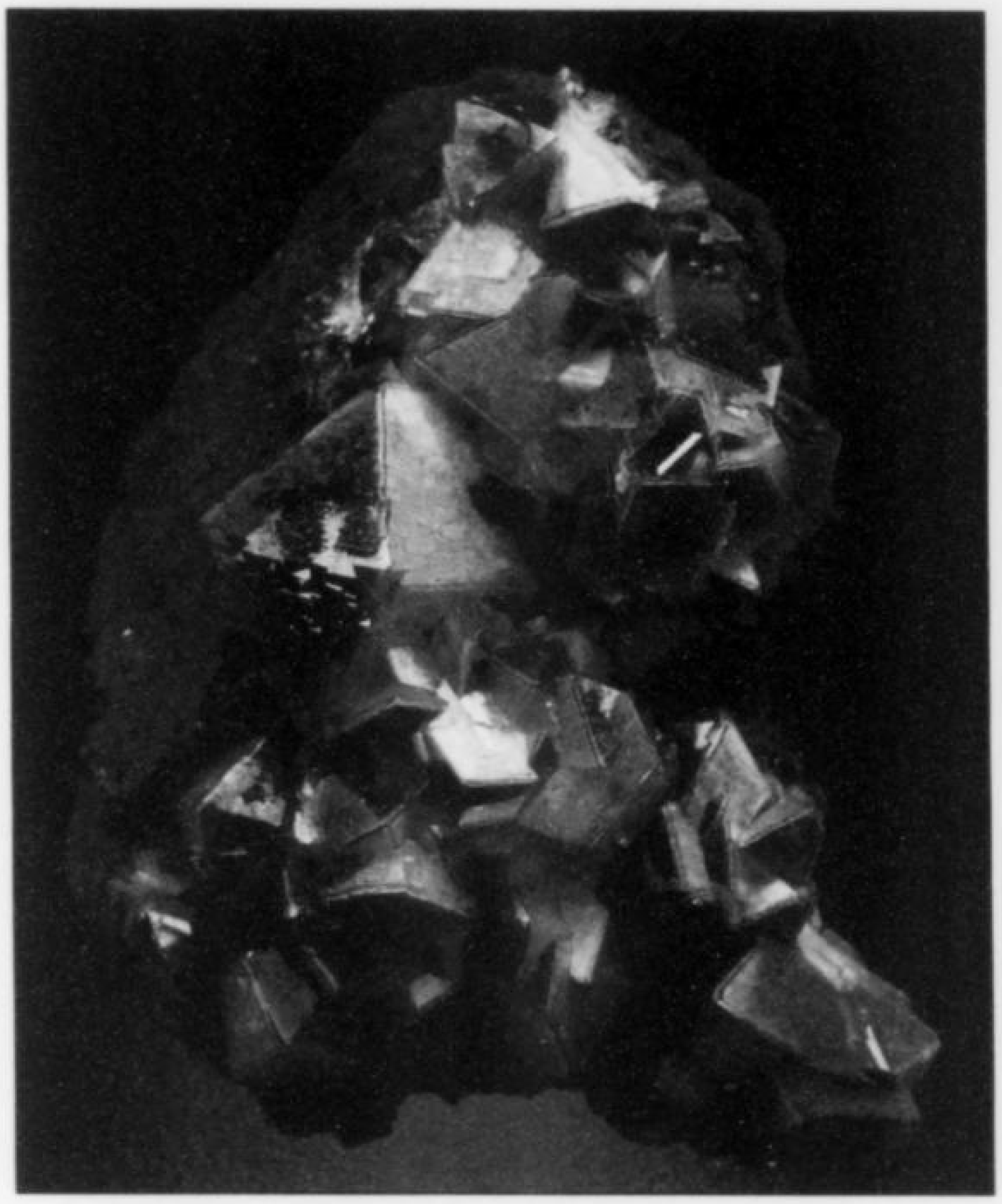


Figure 68. **Dark purple adamite selectively coated by yellow adamite on the prism faces, 2.1 cm, from the Ojuela mine. Ron Pellar collection; Jeff Scovil photo.**

By the time a rising water table had ended collecting in this zone of San Judas, the total yield was about 200 top-quality specimens of purple adamite, plus about 2000 others, as well as some other, much rarer arsenates. About ten meters away from the adamite pockets, 20 flats of scorodite specimens were extracted, including a small handful of outstanding pieces, with blue scorodite crystals to around 2 cm (the best of these specimens are now in the Harvard collection). Four hundred meters away, on Level 6 of La Cigueña, spectacular large blankets of bright red carminite microcrystals were found, as well as a single specimen with a 4-cm spray of acicular pinkish villyaellenite crystals, and microcrystals of what would be the new species lotharmeyerite and ogdensburgite.

Purple adamite crystals have been found at only one other site in the Ojuela mine: the *Tesoro Doce* vein, where specimens were sporadically encountered up to 2001. These crystals are a very deep purple, and some are bicolored purple and yellow, but none are more than 5 mm long.

The chemistry of the San Judas chimney, although grounded in things as mundane as arsenopyrite at the core and manganese oxides in the intermediate "ring," is quite exotic, and seems unique in the world—an unexpected gift of the Ojuela mine both to mineral collectors and professional mineralogists.

Anglesite $PbSO_4$

Anglesite is a common alteration product of galena, and is often partially altered in turn to cerussite. Euhedral crystals are rare, but a few vugs in galena have been found which contain adamantine, highly modified anglesite crystals to 5 cm; predominant forms noted were {101}, {001}, {011} and {111} (Hoffmann, 1967).

Ankerite $Ca(Fe^{2+},Mg,Mn)(CO_3)_2$

Ankerite, commonly stained tan or brown by the oxidation of its ferrous iron, occurs with calcite, barite, fluorite, quartz and stibnite in low-temperature veins in the upper mineralized zones (Hoffmann, 1967).

Apatite Group $Ca_5(PO_4)_3(F,Cl,OH)$

Apatite-group species do not form crystals in the Ojuela mine, although apatite (species unknown) as massive, banded material in botryoidal crusts is found filling veins and fractures. In 2000, an old specimen from the late Joe Cilen's collection, and reportedly from the Ojuela mine, was found to be carbonate-hydroxylapatite—$Ca_5(PO_4,CO_3)_3(OH)$. The specimen had been labeled with the obsolete term "dahlite" (Vajdak, 2001).

Elsewhere in the district, apatite in at least two unusual habits has been found at the **Asterillo mine**, which was worked for phosphate rock for fertilizer during the 1960's (Williams, ca. 1965) and is probably the "apatite mine" noted by Hoffmann (1967); this mine lies southwest of Mapimí, on the western side of the Bufa. Occasionally in the 1960's and 1970's, dealers advertised specimens of eggshell-white, botryoidal "bone collophane" from the Astillero mine. According to Bayliss (2000), "collophane" is an old name for either carbonate-fluorapatite or carbonate hydroxylapatite. The old "collophane" specimens have black dendrites of a manganese oxide on their surfaces, and they show a cream-colored fluorescence (Williams, ca. 1965). Apatite is also found as pseudomorphs and casts after an unknown bladed mineral, possibly gypsum (Hoffmann, 1967)—these specimens also come from the Asterillo mine (Peter Megaw, personal communication, 2003).

Aragonite $CaCO_3$

Hoffmann (1967) observed that white stalactites of aragonite are constantly forming, usually on recrystallized calcite and dolomite, in or near watercourses in the mine workings; actually these formations, often helectitic, are calcite (Mike New, personal commuunication, 2003).

In November 2001, in *San Judas* on Level 7, three exceptional aragonite specimens were found, the largest one almost 30 cm long, with aragonite crystals to about 10 cm. The crystals are tapering prisms which come to a point, white to colorless and translucent to transparent, rising in sprays from cavities in earthy brown goethite gossan. In October 2002, new work in the same area produced several flats of beautiful specimens, to 20 cm across; these are interlocked clusters of lustrous, colorless, transparent, thin-prismatic crystals of aragonite to 3 cm in delicate sprays on goethite matrix.

Arsendescloizite $PbZn(AsO_4)(OH)$

Arsendescloizite was described in 1982 as a new species; the type locality is Tsumeb, Namibia, where pale yellow microcrystals occur (Keller and Dunn, 1982). At the Tucson Show in 1989, one dealership offered ten flats of dark green to bright green botryoidal arsendescloizite, some lightly sprinkled with very small yellow to white crystals of mimetite, from the Ojuela mine (Wilson, 1989). These specimens came from the *lugar* called *San Juditas*, where rich green coatings of arsendescloizite to 25 cm across on matrix, with emerald-green adamite spheres to 1 cm, were collected in 1988.

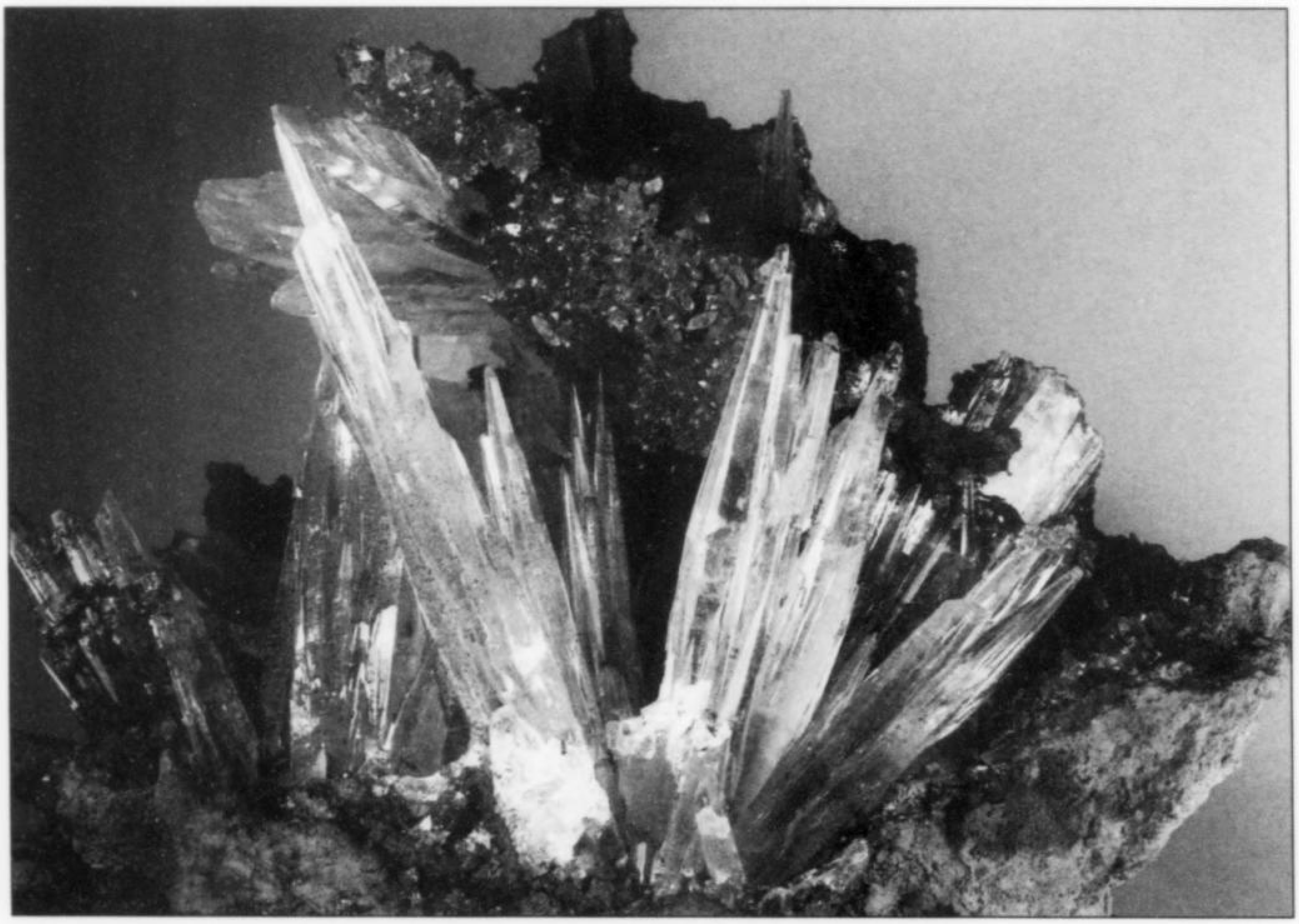


***Figure 69.* Aragonite crystals to 9 cm on limonite matrix, from the Ojuela mine, San Judas chimney (2002). Top Gem specimen; Wendell Wilson photo.**

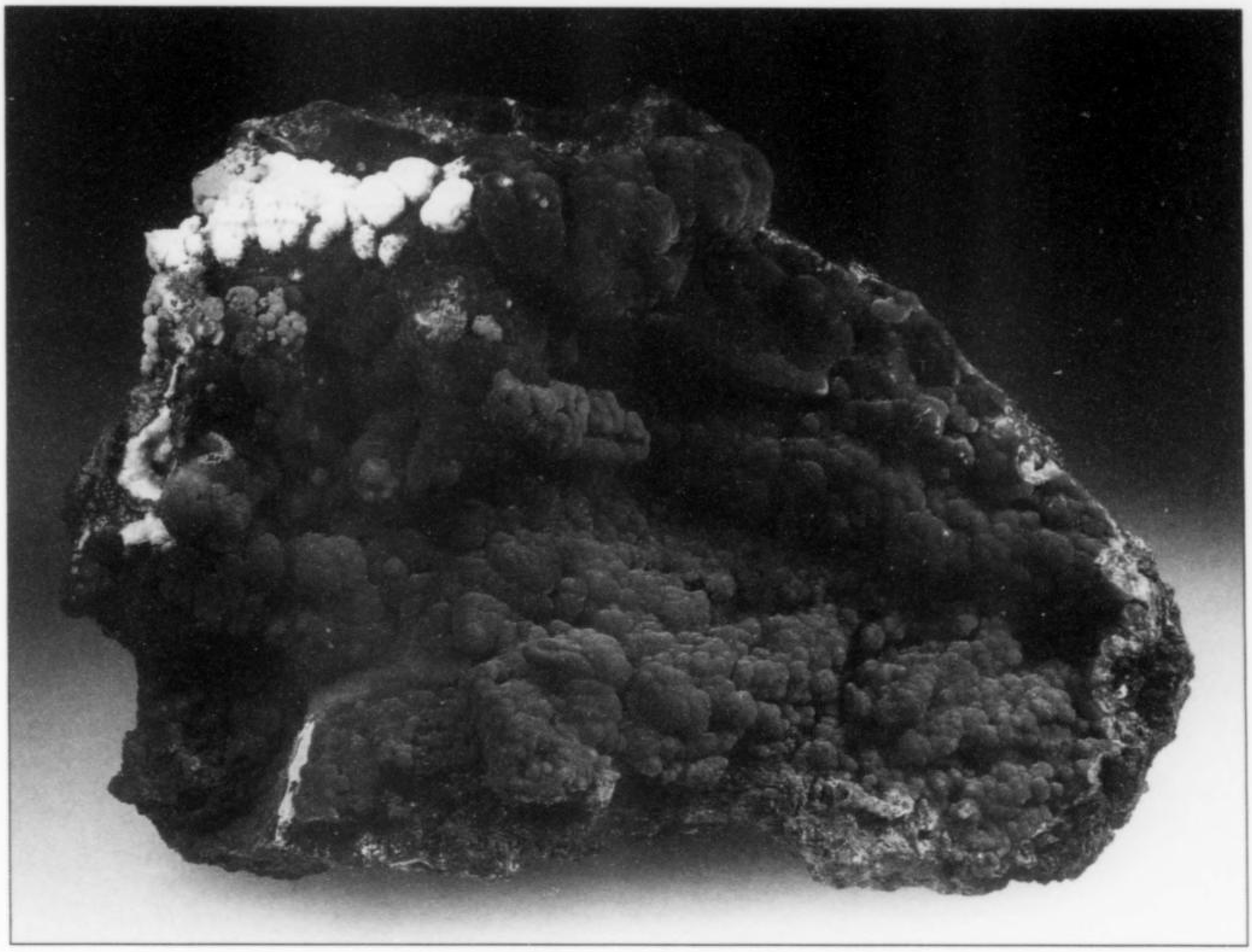


Figure 70. **Botryoidal arsendescloizite with hydrozincite and yellow mimetite, 17 cm, from the Ojuela mine. University of Arizona Mineral Museum collection; Wendell Wilson photo.**

The attractive, satiny green botryoidal arsendescloizite strongly resembles the much more common green mimetite of the Ojuela mine. However, in the extensive Ojuela mine suite in the Miguel Romero collection, now at the University of Arizona, arsendescloizite specimens quite often show white hydrozincite in association, whereas green mimetite never does; yellowish white crystals of mimetite are also commonly present on arsendescloizite (Marcus Origlieri, personal communication, 2003).

Arseniosiderite $Ca_2Fe_3^{3+}(AsO_4)_3O_2 \cdot 3H_2O$

Arseniosiderite specimens were collected in the summer of 1927 by Harry Berman and W. F. Foshag, who found them in dumps just below the old miners' town of Ojuela; presumably the material had come up from somewhere deep in the mine through the Tiro 4 (#4 shaft). The arseniosiderite occurred as fine-grained masses of pale to dark chestnut-brown color and as veinlets in massive scorodite. In a few vugs in the massive material, arseniosiderite forms sharp pseudomorphs after scorodite crystals (these were once called "mazapilite"—Bayliss, 2000), associated with 0.5-mm carminite crystals (Foshag, 1937). Hoffmann (1967) noted arseniosiderite on numerous Ojuela mine specimens, especially from the *America Dos* area, contemporaneous with hemimorphite and partly replacing it. McGowan (2000) notes radial-fibrous aggregates of yellow, yellow-brown, reddish brown, brownish black or black arseniosiderite from an unspecified occurrence in the Ojuela mine; many of these appear to be pseudomorphs after elongate legrandite or köttigite (Peter Megaw, personal communication, 2003).

Arsenopyrite FeAsS

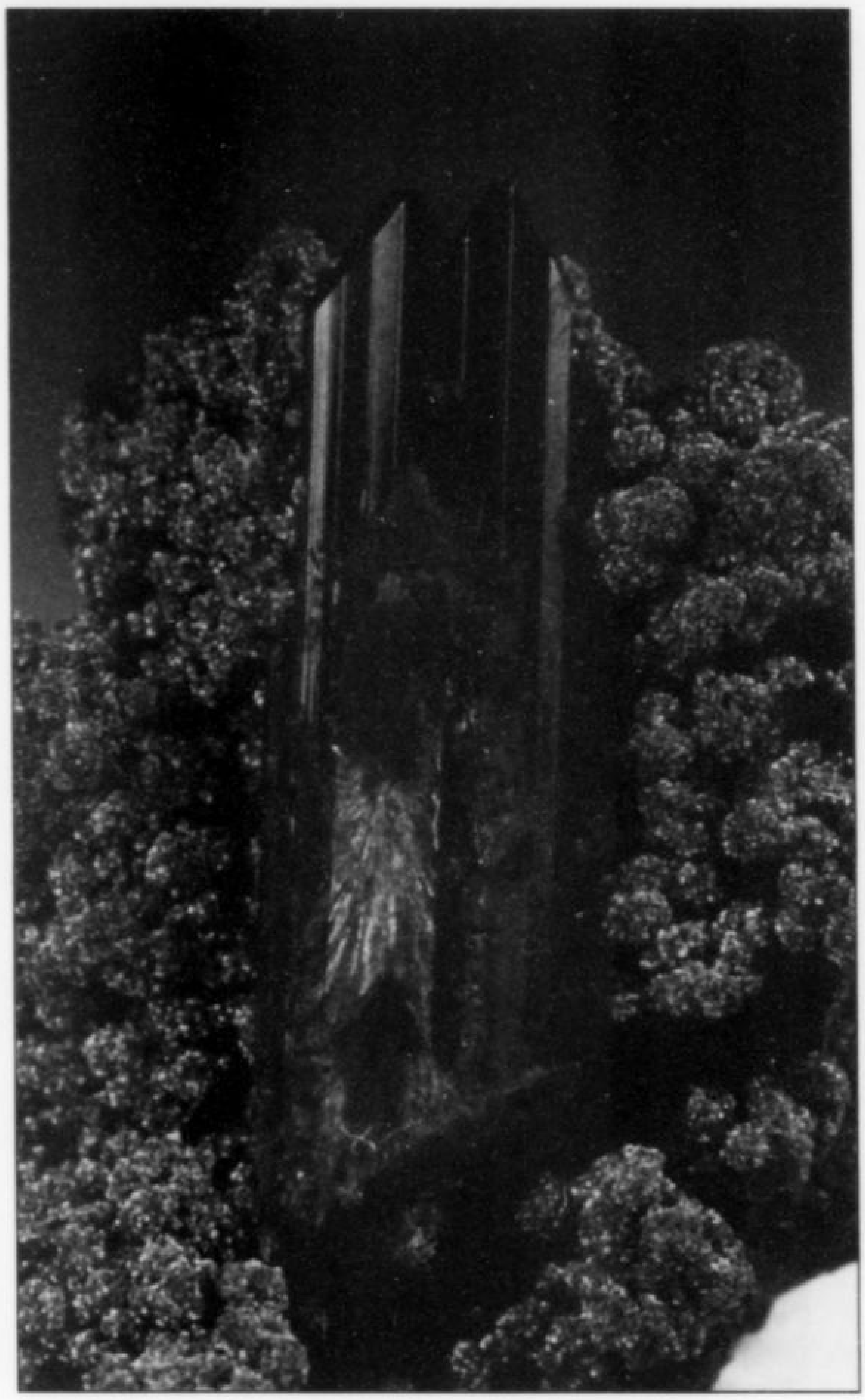
Arsenopyrite, the primary arsenic mineral from which the many arsenate species have altered, has been observed in many polished sections of the primary ores, especially those from deep-lying veins close to the intrusive igneous bodies (Hoffmann, 1967). Euhedral arsenopyrite crystals to 1 cm are abundant on the dumps from deep portions of the Ojuela mine; these are associated with galena, sphalerite, pyrite and earthy goethite. The arsenopyrite crystals are of simple habit, consisting only of prism and basal faces (Hoffmann, 1967).

Aurichalcite $(Zn,Cu^{2+})_5(CO_3)_2(OH)_6$

Aurichalcite in beautiful specimens is one of the signature minerals of the Ojuela mine. It occurs as pale to bright robin's-egg-blue, acicular crystals, with some crystal tufts reaching 3 cm (Panczner, 1987). Aurichalcite is a weathering product of primary zinc sulfide ores, and it alters, in turn, to hydrozincite (Hoffmann, 1967). Jones (1971) suggests that the paler-colored tips of some aurichalcite needle crystals have begun to lose copper, although aurichalcite and hydrozincite, despite their similar structures, do not seem to form a solid solution series, the Ojuela hydrozincite never containing significant copper (Jambor and Pouliot, 1965). Aurichalcite is found on brown goethite matrix, with calcite, plattnerite, fluorite, hemimorphite and barite; much Ojuela mine aurichalcite has a colorless to cloudy white coating of calcite or hemimorphite (Jones, 1971a). Beautiful large clusters of calcite crystals tinted turquoise-blue by aurichalcite inclusions are also known (Turley and Koval, 1987); newer specimens of this type were found, during the years 1999–2002, in *Cumbres* and *San Juan Poniente*, with cuprian adamite and cuprian austinite. Aurichalcite-lined pockets more than 1 meter in diameter and 6 to 7 meters long have been discovered in the Ojuela mine (Panczner, 1987).

Figure 71. **Aurichalcite with fluorite, 3 cm across, from the Ojuela mine. Smithsonian Institution specimen; Wendell Wilson photo.**

Figure 72. **Azurite partially pseudomorphed to malachite, on conichalcite, 2.4 cm, from the Ojuela mine, San Juan Poniente *lugar* (1999). Gene Wright specimen; Wendell Wilson photo.**



During the early 1960's dramatic specimens with matrix plates to 15 cm across, covered completely by delicate blue aurichalcite blankets and tufts, were fairly abundant on the mineral market (Jones, 1971a). These specimens were collected in *Cumbres* in the San Antonio chimney, where aurichalcite associated with azurite, malachite and calcite was found regularly during the 1950's and 1960's; one gorgeous, bright blue specimen is 30 cm across (Manuel Lopez, personal communication, 2002). No aurichalcite specimens remotely comparable to these early ones have been found in the Ojuela mine since the mid-1960's; it is a rare mineral on the market today.

Austinite $CaZn(AsO_4)(OH)$

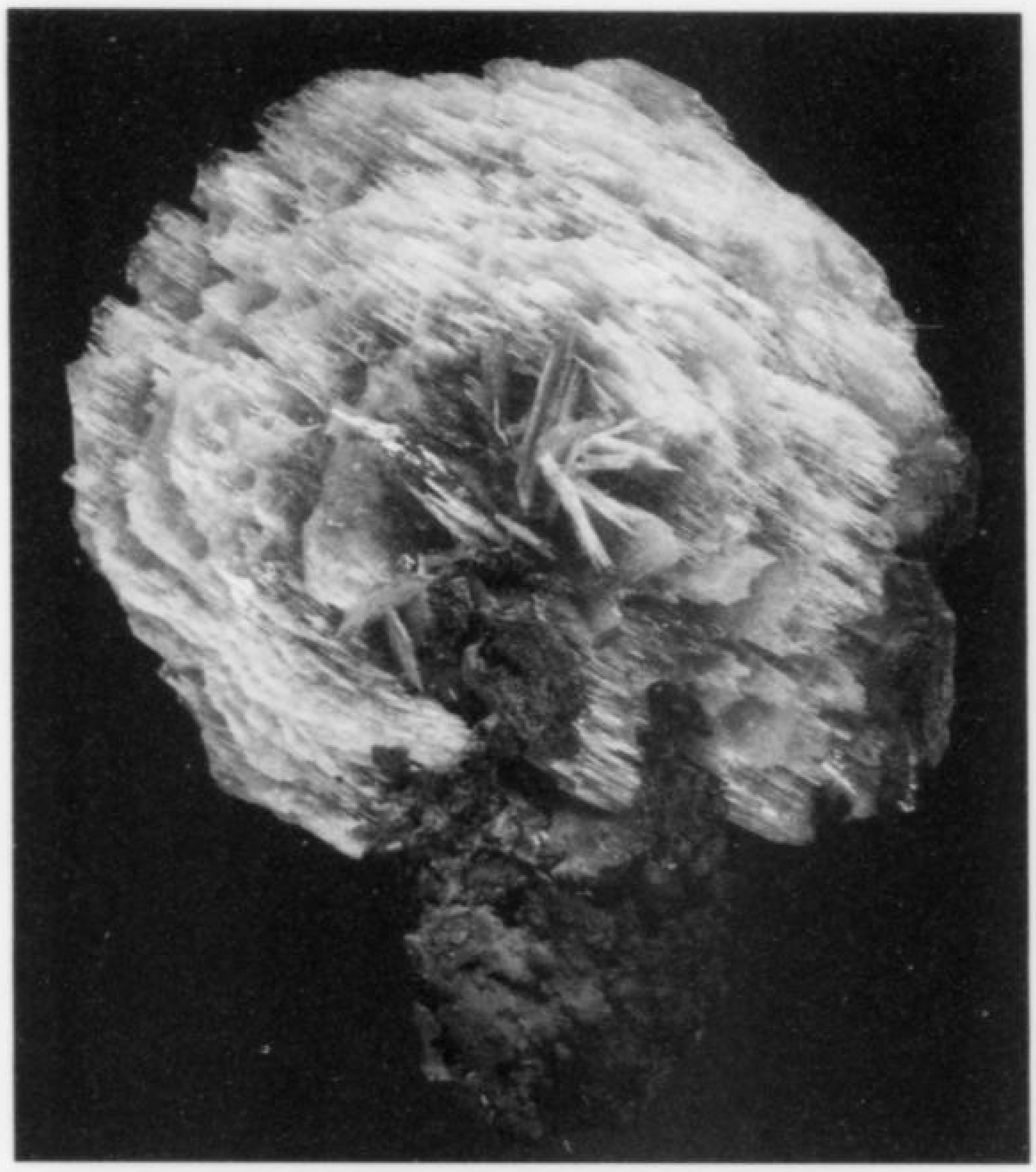
Radiating clusters of colorless to white acicular crystals of austinite, with individual crystals seldom more than 0.7 mm long, occur with manganese minerals in the *America Dos* and *San Juan* areas (Hoffmann, 1967). The species belongs to the adelite group, as does conichalcite, which also occurs at the Ojuela mine. Although Radcliffe and Simmons (1971) assume that a complete solid solution series between austinite and conichalcite must exist, their study found both species at the Ojuela mine to approach pure end-member compositions quite closely, with significant mixing in only one sample tested ($\text{austinite}_{31}\text{conichalcite}_{67}\text{adelite}_{2}$). Overgrowths of conichalcite on cuprian austinite were once known as "barthite" (see under conichalcite, below). Acicular crystals of austinite generally show the simple forms {110} and {111} (Radcliffe and Simmons, 1971).

In the late 1960's there was a find of attractive druses of microcrystals of austinite along the periphery of the "legrandite stope" of the Ojuela mine, i.e. the *Palomes Oriente-San Carlos* collecting areas. (See also under legrandite.) White to creamy gray austinite crystals with overgrowths of transparent, colorless calcite line vugs in goethite (Williams, ca. 1965).

Azurite $Cu_3^{2+}(CO_3)_2(OH)_2$

Azurite specimens from the Ojuela mine are not well known and were never common. Good dark blue crystals and dull blue crusts of azurite are found in the upper oxidation zones of the orebodies; some are coated with a pale blue, water-soluble mineral, probably chalcanthite (Hoffmann, 1967). The mineral may also be found in shear zones and fault zones, associated with gypsum (Hoffmann, 1967).

In *Cumbres* during the 1950's and 1960's, azurite crystals generally smaller than 1 cm were found, forming druses with malachite and aurichalcite. The Ojuela mine's best azurite occurrence was discovered in 1999 on Level 7 in *San Juan Poniente*, and a few flats of beautiful small specimens were extracted. These



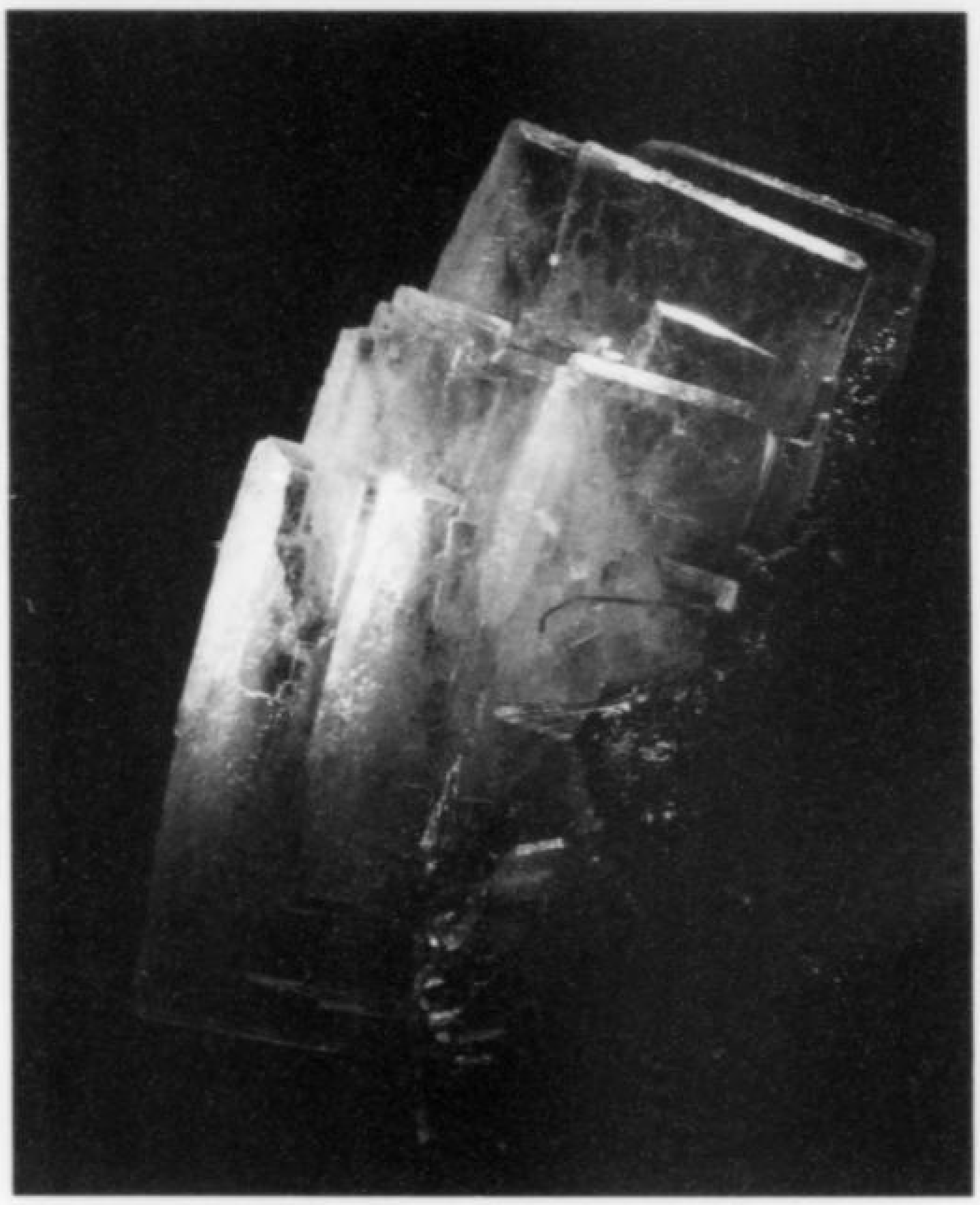


***Figure 74.* Cluster of orange barite crystals, 5.7 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.**

***Figure 73.* *(above left)* Parallel-growth cluster of barite crystals on limonite, 4.9 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.**

***Figure 75.* Pale brown barite crystals, 4 cm, from the Ojuela mine. Smithsonian Institution collection; Wendell Wilson photo.**

show sharp, sword-shaped, transparent deep blue azurite crystals, generally measuring around 7 mm but exceptionally reaching almost 3 cm. They have formed on black matrix of goethite and massive cuprite; most are coated with grayish green mammillary conichalcite, and some of the azurite crystals impale, or are decorated along their sides with, transparent calcite rhombs. In many instances, the azurite is leached out leaving hollow conichalcite epimorphs.

Elsewhere in the district, azurite crystals to 6 cm were once found in the **Descubridora mine** (Mike New, Peter Megaw, personal communications, 2003). Once a major copper mine, the Descubridora (also called **La Cadena**) lies about 35 km west of the Ojuela mine; it is probably the source of the 6-cm azurite crystals which Bancroft (1984) attributes to the Ojuela mine.

Barite $BaSO_4$

Barite has long been known as a common mineral in the upper parts of the primary sulfide orebodies, and in the oxidized zones (Hoffmann, 1967). On the first and second levels of the Ojuela mine, pale blue euhedral barite crystals to 3 cm were found, associated with aurichalcite, plattnerite, murdochite, calcite, fluorite and hydrozincite (Hoffmann, 1967). Panczner (1987) notes white, golden brown and blue barite crystals to 5 cm, associated with mimetite, wulfenite, aurichalcite and other species. In the late 1970's, golden-colored, highly zoned crystals, identified as barite by Curt Segeler (King, 1979), began to emerge on the specimen market; the major associated species were wulfenite and mimetite. About ten years later, attractive Ojuela specimens of golden barite numbering in the hundreds appeared; the crystals are translucent to transparent, thin tabular plates to 3 cm, with somewhat irregular surfaces, on black matrix (Wilson, 1990). Honey-colored, opaque barite crystals to 2.5 cm in sheaf-shaped aggregates to 25 cm have been found from time to time in *San Juan Poniente*.

"Barthite" See under **Conichalcite-cuprian austinite**

Bayldonite $PbCu_3(AsO_4)_2(OH)_2\cdot H_2O$

Apple-green to yellow-green bayldonite in crystals to 4 mm occurs as druses with wulfenite and goethite (Panczner, 1987), and as mammillary concretions with fibrous structure (McGowan, 2000).

Berzelianite Cu_2Se

Small grains of berzelianite admixed with primary ores in *Monterrey* have been identified in thin-section (Hoffmann, 1967).

Beudantite $PbFe_3^{3+}(AsO_4)(SO_4)(OH)_6$

Dark green, brown or black pseudocubic rhombohedral crystals of beudantite have been found in the Ojuela mine (McGowan, 2000). Very recently, beudantite and segnitite, in tiny, yellowish, porous masses, have been noted as the matrix material for 0.1-mm rosettes of the newly described species sewardite (Kolitsch, 2002).

Bindheimite $Pb_2Sb_2O_6(O,OH)$

Bindheimite has been noted as white to gray crusts on goethite, associated with plattnerite, in the Ojuela mine (Johnson, 1962), and as a fibrous to massive, yellow-brown alteration product of sulfides and sulfosalts, particularly in *San Juan Poniente*, where it is found with colorless to white adamite, mimetite, plumbojarosite and hedyphane (Hoffmann, 1967). Some bindheimite samples examined contained considerable quantities of Zn, As, Fe and SO_2, perhaps because of intimate mixing with adamite, goethite and anglesite; a bright orange-yellow specimen proved to contain about 5% silver, suggesting partial substitution by the silver antimonate stetefeldite (Hoffmann, 1967).

Bismuth Bi

Grains and small masses of native bismuth were noted in polished sections of ore from *Monterrey* (Hoffmann, 1967).

Bismuthinite Bi_2S_3

Bismuthinite in grains and euhedral crystals measuring from 2µ to 30µ were noted in polished sections of ore from *Monterrey*; a reaction rim of bismuthinite is often seen separating enargite and galena from later native bismuth (Hoffmann, 1967). Prismatic to acicular bismuthinite crystals from the Ojuela mine may reach 4 mm (McGowan, 2000).

Bornite Cu_5FeS_4

Polished ore sections show bornite as thin rims on grains of chalcopyrite and enargite; an iridescent coating on some chalcopyrite may be bornite (Hoffmann, 1967).

Boulangerite $Pb_5Sb_4S_{11}$

Compact fibrous masses of boulangerite are found in the primary lead ores, associated with pyrite, stibnite, galena and calcite, and partially replaced by jamesonite (Hoffmann, 1967). One analyzed boulangerite specimen from the Ojuela mine contains about 1% silver, perhaps in substitution for lead or perhaps from admixture of a silver sulfosalt (Hoffmann, 1967). Prismatic to acicular boulangerite crystals to 7 mm sometimes form rings (McGowan, 2000).

Brochantite $Cu_4^{2+}(SO_4)(OH)_6$

Dark green acicular crystals of "brochantite" from the upper oxidized zones of the Ojuela mine have often proven to be malachite, and true brochantite is commonly found partially altered to a paler green-colored malachite (Hoffmann, 1967). A few brochantite specimens have come from the dumps above *San Juan Poniente* (Hoffmann, 1967), and acicular tufts to 1 cm have been found with cerussite, malachite and goethite (Panczner, 1987). In 1980/1981, near the surface in *El Pirul*, green sprays of transparent acicular brochantite crystals were found, the sprays reaching 1.5 cm; this is the Ojuela mine's best brochantite.

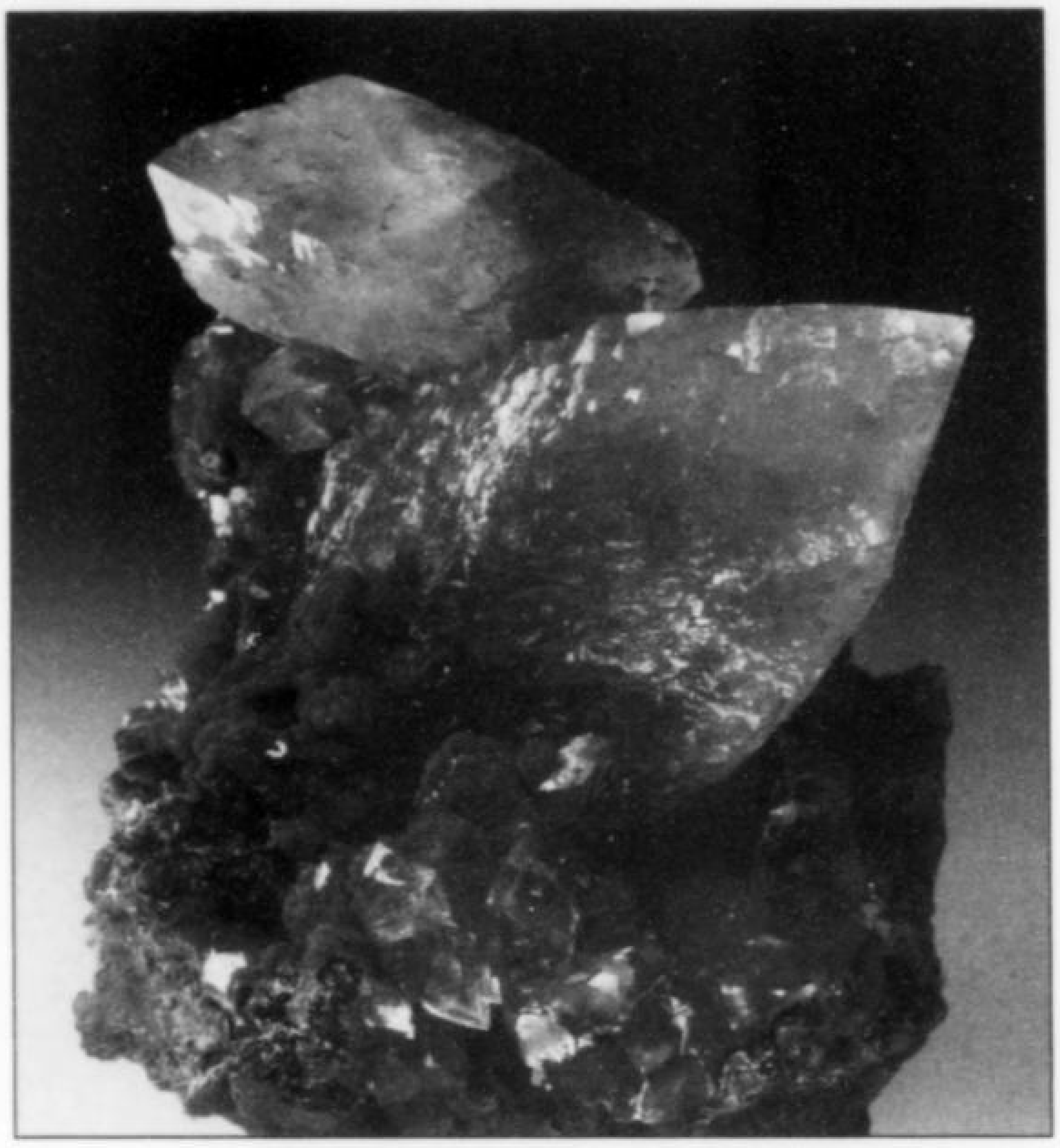


Figure 76. **Calcite crystals on green "barthite" (= conichalcite + austinite), 2.7 cm, from the Ojuela mine. Thomas Moore collection; Wendell Wilson photo.**

Calcite $CaCO_3$

Calcite in the Mapimí district is paragenetically late, and is associated with nearly every other major mineral species (Hoffmann, 1967). In the Ojuela mine, colorless to white, pink, yellow and gray calcite is widely distributed, in crystals to 5 cm (Panczner, 1987). Crystal habits vary considerably; Hoffmann (1967) suggests a pattern of correlation between morphology and mineral assemblages, the simpler calcite crystals tending to occur with zinc species, the highly modified ones with copper and lead species. Perhaps the most common habit of Ojuela calcite is as white, opaque to translucent, simple rhombohedrons of vaguely "Tsumeb-like" aspect, as jumbled groups, solid vug linings, or parallel-growth aggregates. Calcite of this type has been found almost everywhere in the mine—and is presently being found in quantity with the wulfenite crystals and green mimetite on Level 7 of *Campana*.

In the early 1960's, acute rhombohedral calcite crystals, some in arborescent groupings with malachite on a goethite matrix, could be collected on the dump at the *America Dos* entrance (Johnson, 1962). In the 1960's, bright blood-red calcite crystals, perhaps colored by fine-grained inclusions of litharge or minium, came from the Ojuela mine, probably from *San Juditas*, where, in 1981, very similar red crystals were discovered, with individuals to 5 cm in groups to 30 cm. In the mid-1980's, bright blue calcite crystals colored by fine-grained inclusions of aurichalcite emerged (Panczner, 1987; Turley and Koval, 1987). Other calcites from the district have inclusions of tufted malachite (Bancroft, 1984) or of hemimorphite (Johnson, 1962).

The miners recall a few more notable occurrences of calcite. In 1983 in *La Cigueña*, transparent and colorless calcite was found with carminite (see entry below), as steep scalenohedrons to 4 cm; beautiful plates to 15 cm covered with plush-red carminite microcrystals are studded with these lustrous, waterclear calcite crystals. In *San Juan Poniente*, white or yellow to colorless, stepped aggregates of calcite to 5 cm occur on green conichalcite; blue, aurichalcite-included calcite crystals are known from this site as well. In 2000, a few flats of specimens with spherical rosettes, 3 to 5 cm in diameter, of platy colorless calcite on dark gray dolomite matrix were produced.

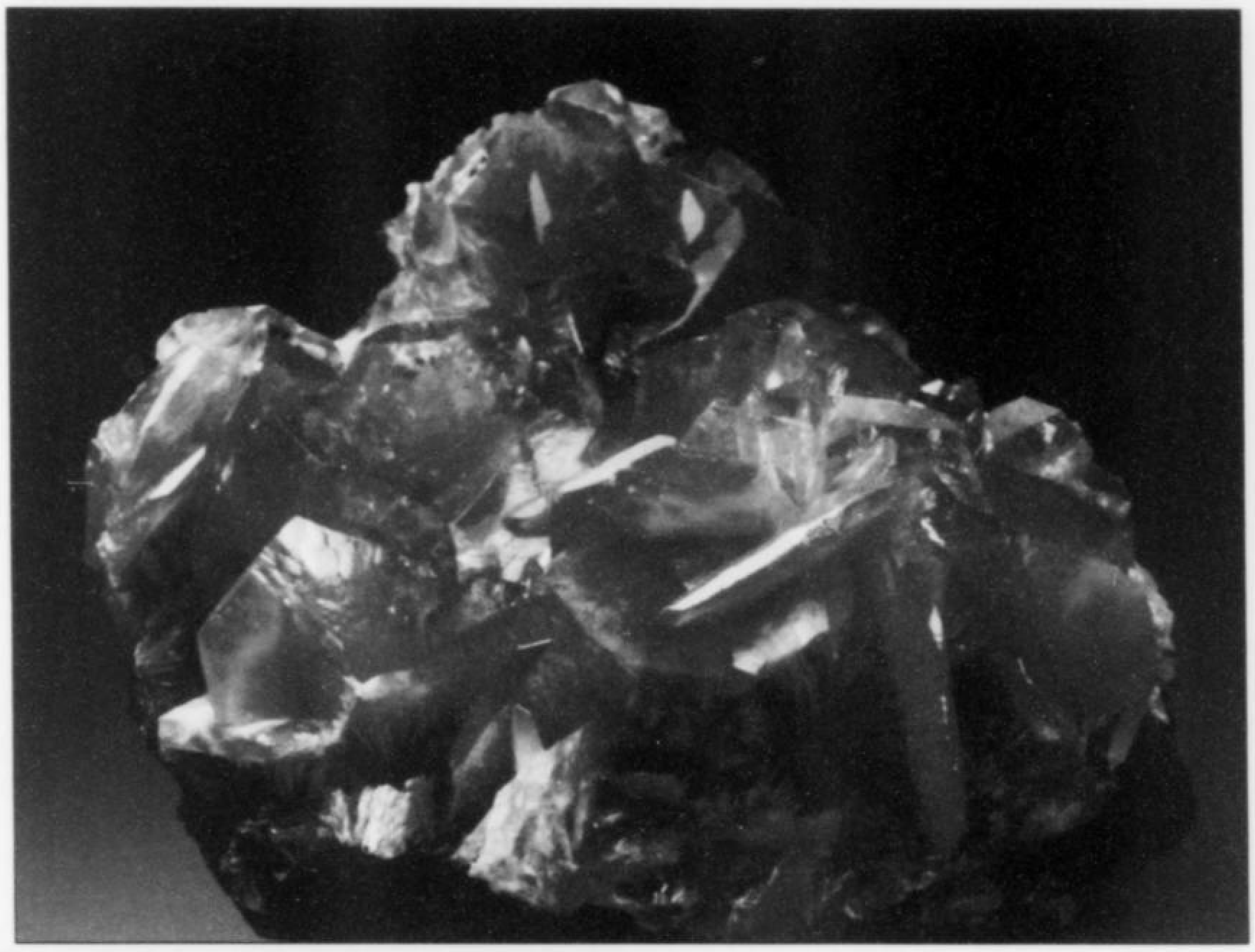


Figure 77. **Aurichalcite-filled calcite crystal cluster, 6 cm, from the Ojuela mine. Mary and Gardiner Miller collection; Wendell Wilson photo.**

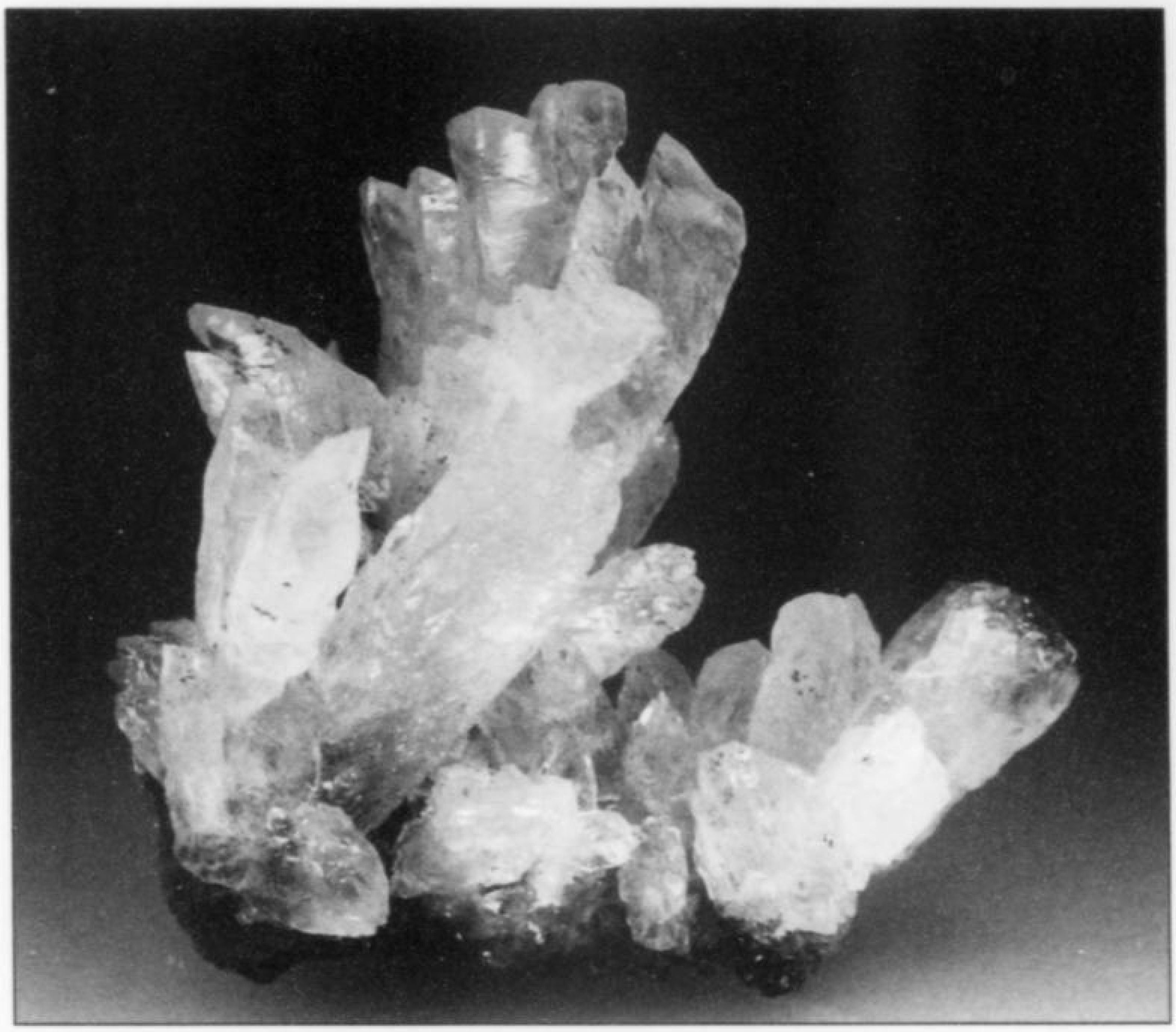


Figure 78. **Calcite crystal cluster with adamite, 6 cm, from the Ojuela mine. Pat Hendrick collection; Jeff Scovil photo.**

Elsewhere in the district, white, highly modified calcite crystals were found in the **La China** and **La Reina mines** (Hoffmann, 1967).

Carminite $PbFe_2^{3+}(AsO_4)_2(OH)_2$

Carminite was first found at the Ojuela mine in the summer of 1927, when William F. Foshag and Harry Berman collected carminite microcrystals, just below what is now the clearing adjoining the Ojuela miners' village. The carminite crystals from this occurrence are acicular to lath-like, aggregated into sheaf-like forms and radiating tufts; individual crystals do not exceed 0.5 mm (Foshag, 1937), and the aggregates do not exceed 2 mm (Hoffmann, 1967). This carminite is highly lustrous, and the crystals are markedly pleochroic, pale yellowish red along x and dark carmine-red along y and z (Hoffmann, 1967). The crystals were found in cavities of massive crystalline scorodite, with seams of arseniosiderite and tiny amounts of dussertite (Foshag, 1937). Hoffmann (1967) collected carminite in masses of cerussite, anglesite, mimetite, wulfenite and plumbojarosite, from a dump above *San Juan Poniente* and with jarosite at Foshag's original site; he reports that these carminite crystals average only 0.2 mm, although according to Panczner (1987) they reach 1 cm.

Panczner (1987) notes that a pocket found in the early 1980's produced crystallized calcite covered with crystals of carminite;

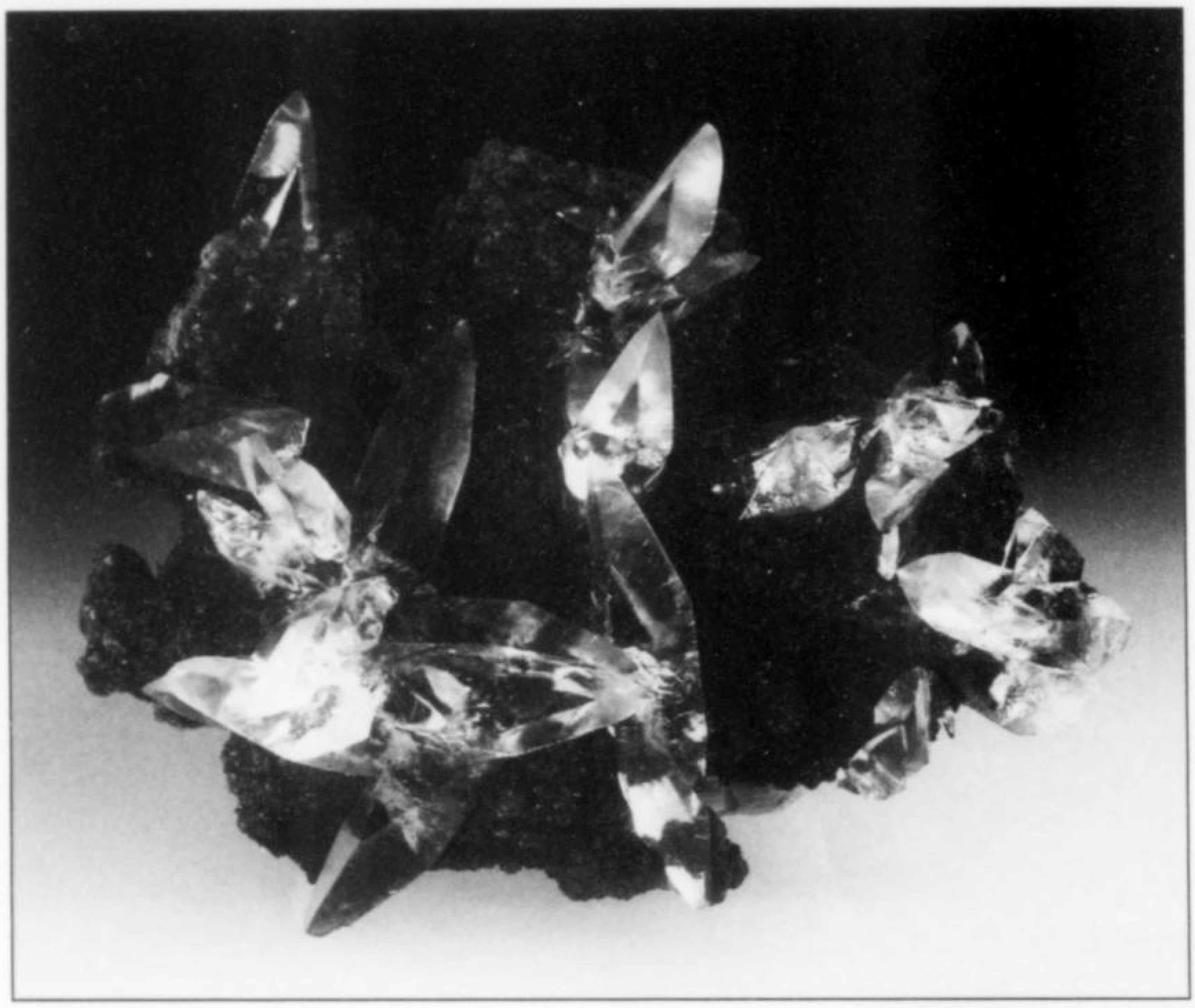
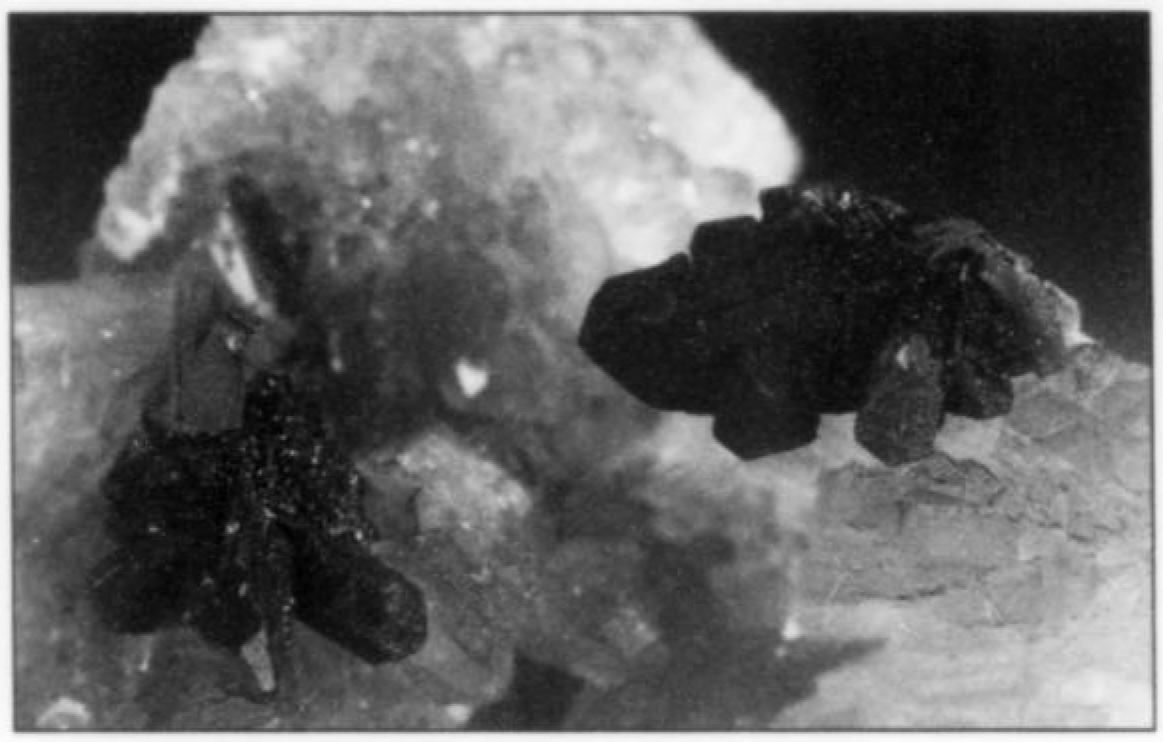


Figure 79. **Calcite crystals on red carminite, 5.7 cm, from the Ojuela mine, La Cigueña *lugar*. Dawn Minette collection; Wendell Wilson photo.**

Figure 80. **Cerussite twins to 9 mm on calcite, from the Ojuela mine. Terry Stambaugh collection; Wendell Wilson photo.**



these specimens came from *La Cigueña* and were rescued for posterity when Mike New came upon two ore cars full of them and gathered 10 flats' worth, then purchased an additional ten flats from a miner. The lustrous red carminite microcrystals blanket matrix expanses to 15 cm across, and the plush coatings host what is perhaps the Ojuela mine's most beautiful calcite, in lustrous, waterclear, steep scalenohedrons to 4 cm.

Kolitsch (2002) speculates that re-examination of old "carminite" specimens from the Ojuela mine may reveal that some of the material is in fact the recently described calcium analog sewardite.

Cassiterite SnO_2

Small, blackish brown acicular crystals of cassiterite were found in *Monterrey*, in contact-metasomatized limestone (Hoffmann, 1967).

Celestine $SrSO_4$

Celestine is rare in the Ojuela mine; on the upper levels it was occasionally found as colorless to pale blue crystals to 2 cm (Panczner, 1987).

Elsewhere in the district, however, celestine has been found in what Peter Megaw (personal communication, 2003) describes as "about a gazillion localities," almost entirely as mediocre specimens (the very good celestines once sold in the Bermejillo rock shops actually came from large celestine mines in central Coahuila State). Hoffmann (1967) mentions celestine from the uppermost zones of mineralization in Mapimí district mines, associated with fluorite, barite, calcite and manganese oxides.

Cerussite $PbCO_3$

Cerussite, once one of the main ore minerals in the district, is an alteration product of galena and anglesite most commonly noted from the oxidized ore zones of the Ojuela mine (Panczner, 1987). Most cerussite in the mine appears as banded alteration rims on banded anglesite, which in turn rests on massive galena (Hoffmann, 1967). Reticulated clusters of twinned cerussite crystals have also been found, with twinning on both {110} and {130} (Hoffmann, 1967). The best cerussite specimens are isolated twins, with twinning on {130}, found in masses of goethite, mimetite, wulfenite and massicot (Hoffmann, 1967); these crystals reach 2 cm (Panczner, 1987). Cerussite pseudomorphs after anglesite and hemimorphite (?) are associated with rosasite, plattnerite, nantokite, malachite and aurichalcite at the Ojuela mine (Hoffmann, 1967; Panczner, 1987).

Chalcanthite $Cu^{2+}SO_4$

Massive or fibrous chalcanthite is found in gouge zones along faults and fractures in the mine workings; when pure it is clear sky-blue, but admixtures of melanterite or goethite may tint it green or brownish green (Hoffmann, 1967).

Chalcocite Cu_2S

Massive chalcocite as partial-replacement rims a few microns thick on chalcopyrite or other copper-iron sulfides has been seen in oxidized zones at *America Dos* (Hoffmann, 1967).

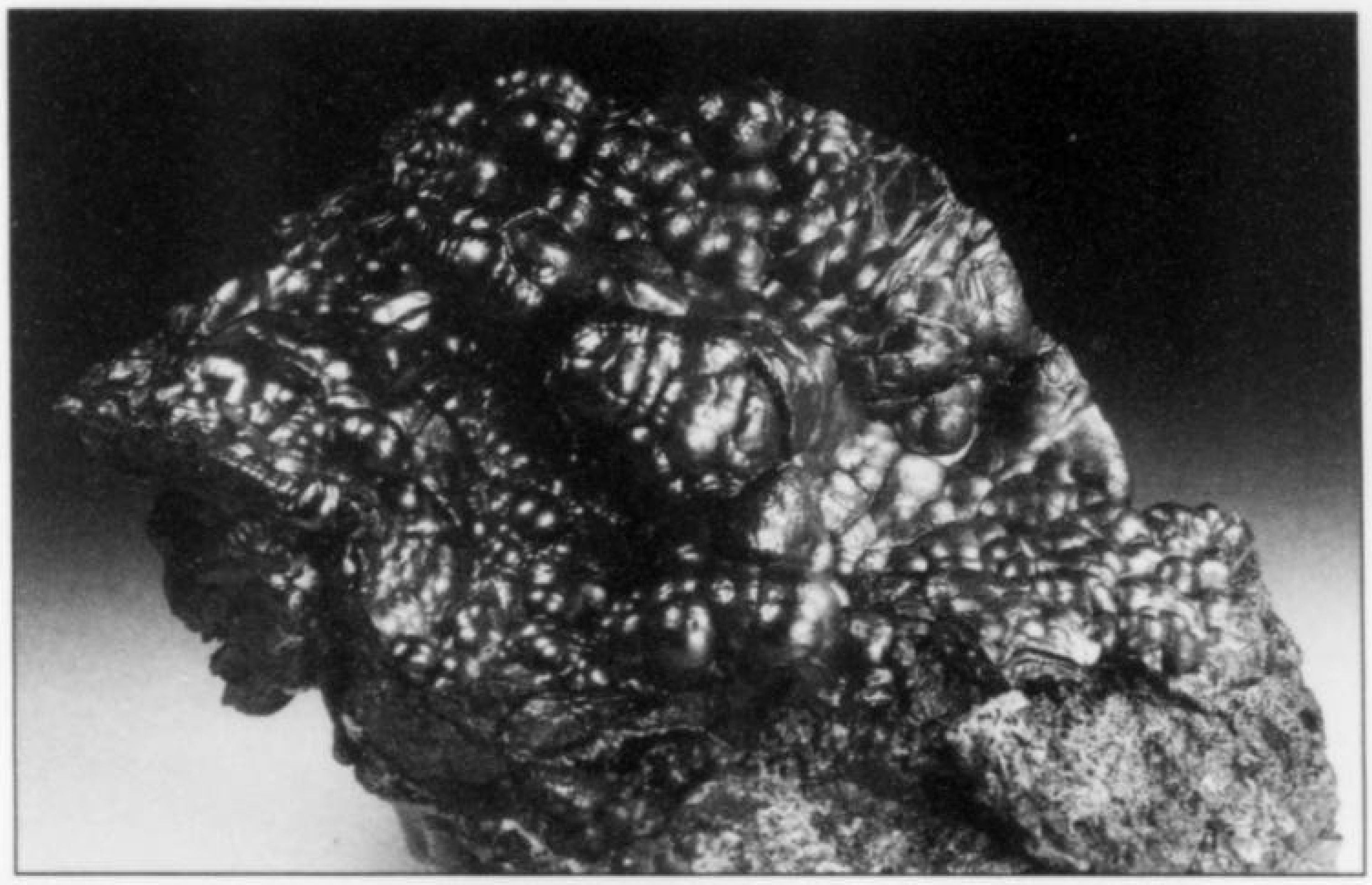


Figure 81. Botryoidal chalcophanite, 10.5 cm, from the Ojuela mine. Terry Stambaugh collection; Wendell Wilson photo.

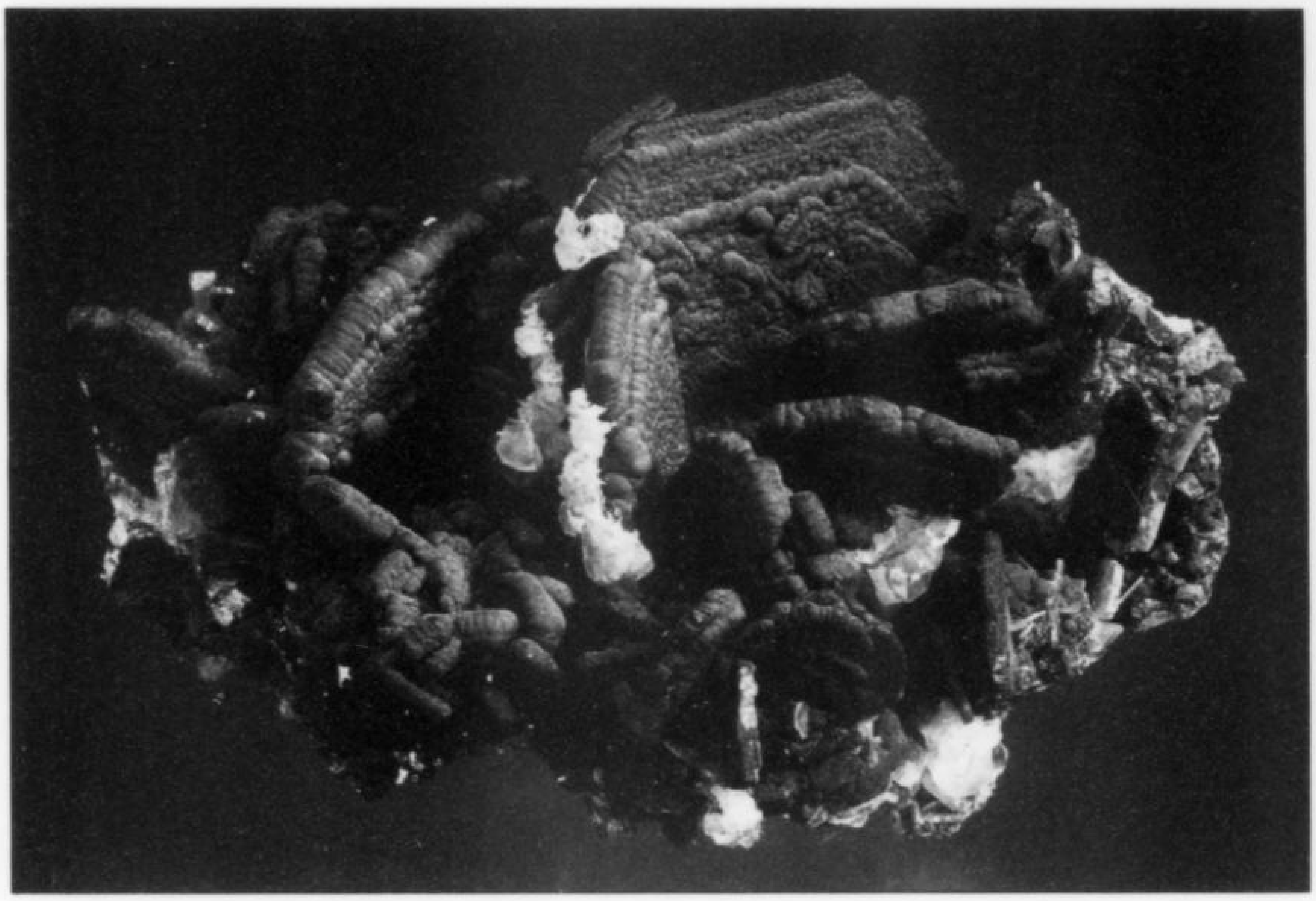


Figure 82. Dark green duftite coating wulfenite, 8.5 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.

Chalcophanite $(Zn,Fe^{2+},Mn^{2+})Mn_3^{4+}O_7 \cdot 3H_2O$

Chalcophanite has been found in fairly attractive specimens in *La Esperanza* in the Ojuela mine: thin, velvety, grayish black or bluish black botryoidal crusts and tiny crystals on goethite, with adamite, calcite and smithsonite (Johnson, 1962; Panczner, 1987).

Elsewhere in the district the mineral occurs in numerous mines (Hoffmann, 1967), and is one of the components of the mixed manganese oxide material that the miners call simply "manganeso," and mineralogists used to call "wad."

Chalcopyrite $CuFeS_2$

Chalcopyrite is the most important primary copper mineral in the Mapimí district, occurring as masses partially replacing earlier sulfides, but it has not been found in crystals (Hoffmann, 1967; Panczner, 1987).

Chenevixite $Cu_2^{2+}Fe_2^{3+}(AsO_4)_2(OH)_4 \cdot H_2O$

Pale olive-green botryoidal crusts of chenevixite about 0.1 mm thick on pale yellow massive mimetite were found in *San Juan Poniente*; the material is intergrown with the mimetite, and X-ray patterns show lines characteristic of both species (Hoffmann, 1967).

Chlorargyrite AgCl

In the early years of mining in the Mapimí district, chlorargyrite was an important silver ore (Panczner, 1987), found in the upper oxidation zones in greenish gray grains with mimetite, cerussite, anglesite and wulfenite (Hoffmann, 1967). Chlorargyrite from the Ojuela mine is rich in bromine (Panczner, 1987), and in the old days might have been called "embolite" (a now-discredited term) as was similar material from Broken Hill, Australia. Today, however, the accepted terminology for describing the series involves only the terms chlorargyrite, bromine-rich chlorargyrite, chlorine-rich bromargyrite, and bromargyrite. No crystals have been seen in material from the Ojuela mine, where the silver chloride-bromide is intimately intermixed with the other oxidized species. In *San Judas* in 1981, collectors working the purple adamite zone encountered a chlorargyrite body which produced about 900 kilograms of very rich silver ore (Mike New, personal communication, 2002).

Chrysocolla $(Cu^{2+}, Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$

Near-surface occurrences of chrysocolla have been noted in numerous prospect pits in the district; no known specimens are verifiably from the Ojuela mine. Pale blue to almost white, amorphous material fills fractures and small cavities, and unsubstantiated reports tell of large, fine blue masses of chrysocolla (probably heavily silicified) having been found sometime before the 1960's, and cut into gems (Hoffmann, 1967). Pseudomorphs of chrysocolla after malachite, rosasite and aurichalcite, some with unaltered cores, have also been found (Hoffmann, 1967; Stambaugh, 2002).

Clausthalite $PbSe$

Small grains of clausthalite, some of them partially replaced by emplectite, occur in ores with umangite, sphalerite, pyrrhotite, bismuth and enargite (Hoffmann, 1967).

"Collophane" See **Apatite Group**

Conichalcite $CaCu^{2+}(AsO_4)(OH)$

The well-known pale to dark olive-green or bright green botryoidal crusts once known as "barthite" have proven to consist of overgrowths of conichalcite on cuprian austinite; "barthite" is now considered an obsolete term (Bayliss, 2000). This material occurs commonly in the oxidized zones of the Ojuela mine, as crusts, small masses, and microcrystals on stalactitic goethite or hematite (Johnson, 1962). Associated species include calcite, malachite and occasionally mimetite, these having preceded conichalcite-cuprian austinite in the goethite vugs (Hoffmann, 1967). Adamite is also sometimes associated; two years ago, Paul Hlava found abundant cuprian adamite on some Ojuela mine conichalcite specimens (Peter Megaw, personal communication, 2003).

Hoffmann (1967) endorses the conclusion of Fischer (1944) that a complete substitution series between conichalcite and austinite must exist, but reports that his studies of the Ojuela material show two discrete phases: a colorless zinc arsenate with some copper (cuprian austinite) overlain by crusts and tiny pleochroic crystals of a nearly pure copper arsenate (conichalcite); Fischer too, according to Hoffmann (1967), found colorless austinite overlain by green conichalcite (then called "higginsite"). As mentioned above, the studies of Radcliffe and Simmons (1971) also found no significant mixing of the two phases at Mapimí.

Green crusts of conichalcite with stepped calcite crystals to 5 cm have come from *San Juan Poniente*. The mine's best conichalcite (sold as "barthite" in the late 1970's) was found around 1975 in *San Carlos*, Level 2: a *lugar* which the miners call *"Manganeso"* for its abundance of black manganese oxides. Here, 4-cm "trees" of bright green conichalcite, with individual crystals to 5 mm, perch on goethite matrix; these specimens were marketed by John Whitmire. In 1996 about 15 flats of conichalcite epimorphs after azurite crystals to 5 mm were produced; conichalcite replacing forests of azurite blades makes for exceptionally attractive specimens.

Elsewhere in the district, numerous small mines and prospects have yielded microcrystals of conichalcite.

Copiapite $Fe^{2+}Fe^{3+}_4(SO_4)_6(OH)_2\cdot20H_2O$

In the Mapimí district, copiapite is found as an alteration product of pyrite and arsenopyrite on several old mine dumps. Pale yellowish white to pale yellow botryoidal coatings on pyrite-bearing boulders have proven to be copiapite; elevated amounts of arsenic in these coatings testify to the presence of arsenopyrite in the original ore material (Hoffmann, 1967).

Copper Cu

Native copper crystals to 6 mm have been noted from the Ojuela mine (Panczner, 1987). Here and **elsewhere in the district**, copper occurs as subhedral crystals and thin wires on samples of ore from oxidized zones, associated with tenorite, cuprite, goethite and delafossite, and as small wires and crystals enclosed in gypsum fracture-fillings, with exposed areas of the copper altered to cuprite and malachite.

Covellite CuS

In the Ojuela mine, covellite is found replacing arborescent crystal masses of native copper on tenorite and goethite, with cuprite and delafossite (Hoffmann, 1967).

Elsewhere in the district, covellite is widespread as a minor constituent of the primary ores and as partial replacements of chalcopyrite and other copper sulfides (Hoffmann, 1967); crystals to 6 mm have been noted (Panczner, 1987).

Cryptomelane $K(Mn^{4+},Mn^{2+})_8O_{16}$

Cryptomelane is the most common of the manganese oxides in the manganese deposits on the western side of the Sarnoso Stock, and is a component of the "manganeso" bodies in the Ojuela mine. Massive cryptomelane may be partially replaced by other manganese oxides or groutite in fractures and on weathered surfaces (Hoffmann, 1967).

Cuprite Cu_2O

Euhedral, blood-red modified cubic crystals of cuprite occur in small vugs on botryoidal goethite in the Ojuela mine, with copper and tenorite (Hoffmann, 1967); these crystals do not exceed 4 mm (Panczner, 1987).

Elsewhere in the district, cuprite is a fairly common alteration product of chalcopyrite, and itself alters to tenorite, native copper, malachite and chrysocolla (Hoffmann, 1967).

Delafossite $Cu^{1+}Fe^{3+}O_2$

Both in the Ojuela and in mines **elsewhere in the district,** brown to black botryoidal crusts of delafossite are commonly seen on masses of goethite, cuprite and tenorite; rosette-shaped crystal aggregates and elongated crystals to 4 mm have also been found (Hoffmann, 1967; Panczner, 1987).

Descloizite $PbZn(VO_4)(OH)$

Descloizite, the most common vanadium-bearing mineral in the Mapimí district, occurs as dark brown tabular crystals to 4 mm on the first level of the Ojuela mine, associated with barite, wulfenite, aurichalcite, rosasite, hydrozincite, plattnerite and murdochite (Panczner, 1987)

Elsewhere in the district, it occurs with fluorite in the **La China** and **La Reina** fluorite mines, in the mountains directly west of La Bufa (Hoffmann, 1967).

Diopside $CaMgSi_2O_6$

In *Monterrey*, euhedral, dark green, lath-like crystals of diopside to 3 cm occur with pyrrhotite and other sulfides (Hoffmann, 1967).

Dolomite $CaMg\ (CO_3)_2$

In the Mapimí district, where orebodies occur as replacements of dolomitic limestone, it is not surprising that veins and sugary white masses of dolomite are common in the orebodies generally (Johnson, 1962; Hoffmann, 1967). Euhedral dolomite crystals line fractures in limestone that later filled with quartz (Hoffmann, 1967), and crystals to 4 cm—not necessarily from the Ojuela mine—are associated with quartz and goethite (Panczner, 1987).

Duftite $(Pb,Ca)Cu(AsO_4)(OH)$

The calcium-rich duftite of Mapimí was called "duftite-α" by Hoffmann, but this term is obsolete (Bayliss, 2000). Dark olive-green encrustations and botryoidal masses of duftite on pale yellow wulfenite occur at the Ojuela mine, with calcite and mimetite in cavities in goethite and manganese oxides (Hoffmann, 1967; Panczner, 1987).

Dussertite $BaFe^{3+}_3(AsO_4)_2(OH)_5$

Dussertite is one of the rare arsenates found by Foshag and Berman in 1927 on a dump near the town of Ojuela, with scorodite, carminite, arseniosiderite and "mazapilite" (an old term for

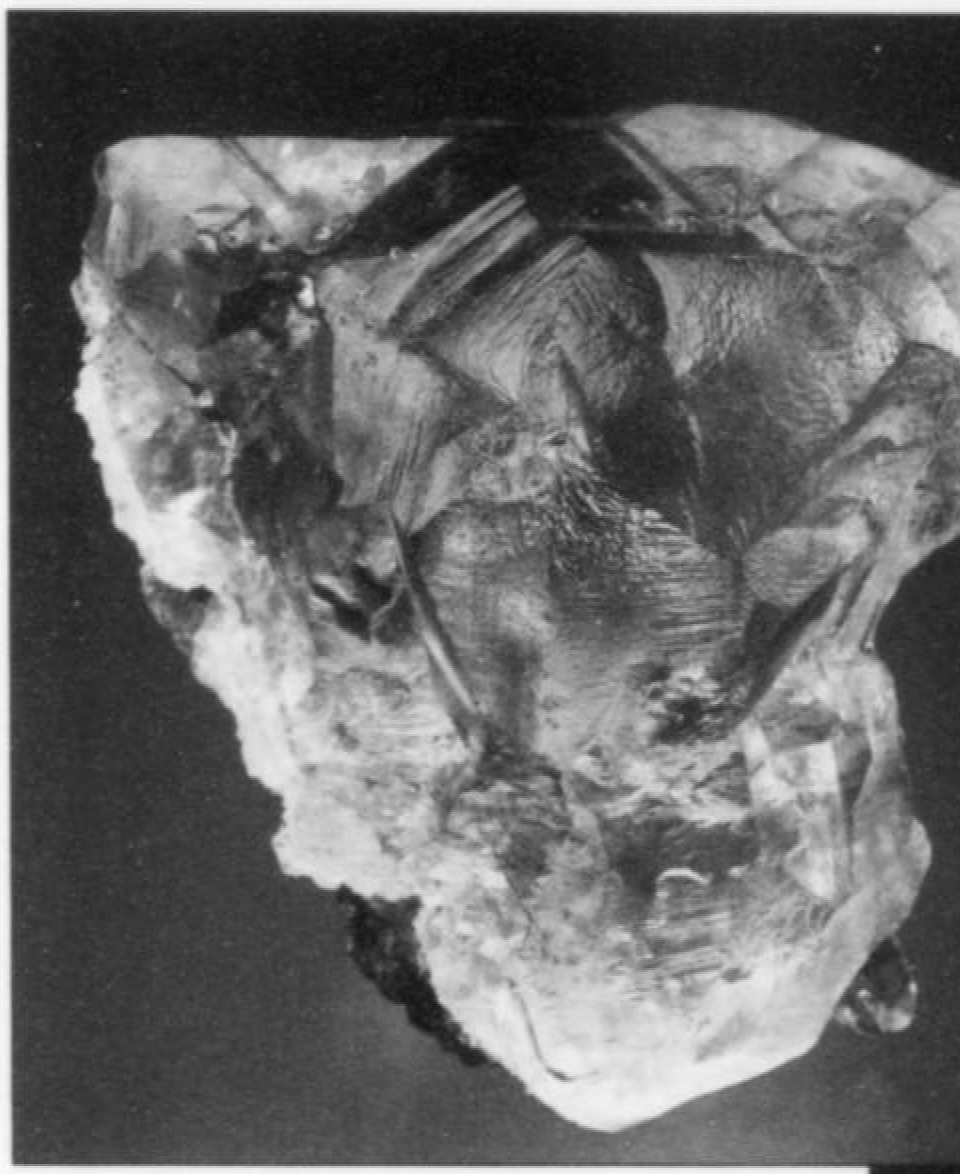


Figure 83. **Fluorite crystal, 3.8 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.**

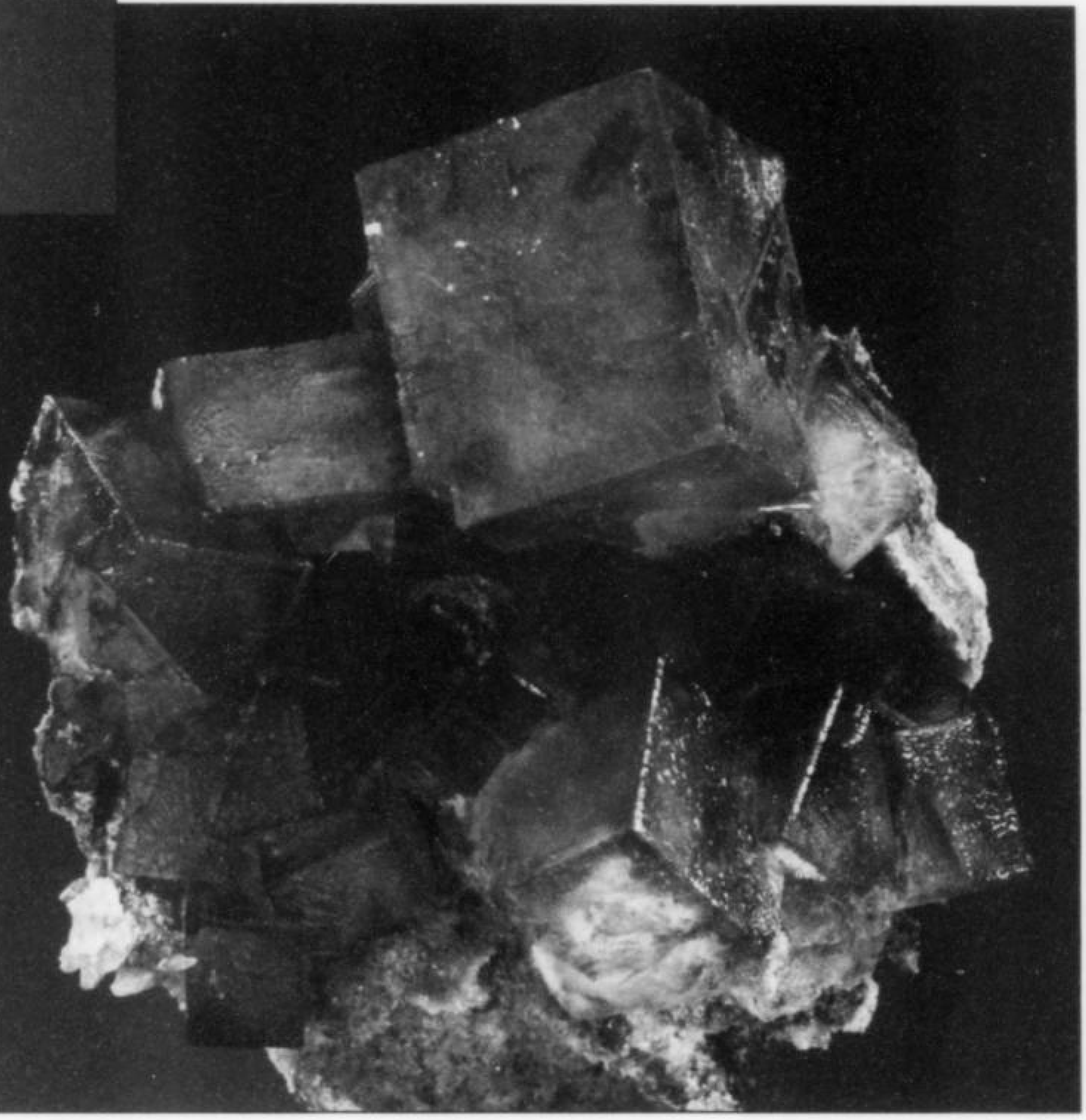


Figure 84. **Fluorite crystal cluster, 6.6 cm, from the Ojuela mine. Wayne and Dona Leicht specimen; Jeff Scovil photo.**

arseniosiderite pseudomorphous after scorodite; Bayliss, 2000). Dussertite occurred as thin bands between carminite and scorodite, and in small, clear pistachio-green masses and microcrystals in arseniosiderite (Foshag, 1937). Pale green, flattened crystals of dussertite are sometimes grouped in rosettes (Johnson, 1962) and reach 4 mm (Panczner, 1987).

Emplectite $CuBiS_2$

Polished sections of ore from *Monterrey* show massive emplectite associated with pyrrhotite, galena, sphalerite, bismuth, bismuthinite, enargite and umangite (Hoffmann, 1967).

Enargite Cu_3AsS_4

Enargite, one of the earlier sulfides in the primary mineral assemblage at Mapimí, constituted the main copper ore species in deeper portions of the deposits; it is associated with arsenopyrite, pyrrhotite, galena and chalcopyrite, and is commonly replaced by marcasite (Hoffmann, 1967). No crystallized enargite is known from the Ojuela mine.

Feitknechtite $\beta\text{-}Mn^{3+}O(OH)$

In the Ojuela mine the rare manganese oxide species feitknechtite is found with the other "manganeso" oxides (Panczner, 1987); it occasionally forms black or brownish black, thin hexagonal plates (McGowan, 2000).

Ferrimolybdite $Fe_2^{3+}(Mo^{6+}O_4)_3 \cdot 8H_2O$ (?)

Hoffmann (1967) observed what he called ferrimolybdite on only one specimen, containing a small rosette of partially altered molybdenite. Some masses of goethite and/or bindheimite were observed to contain yellow aggregates to 1 mm of a molybdenum-iron oxide; X-ray diffraction patterns were not conclusive, but semiquantitative spectrographic analyses showed Mo to be the major constituent, so Hoffmann (1967) used the term "molybic ochre" for the material. According to Bayliss (2000), the old "molybdic ochre" = ferrimolybdite.

Fluorite CaF_2

In the most commonly seen Ojuela mine specimens, fluorite appears as wine-red to purple cubic crystals (Johnson, 1962; Bancroft, 1984), but Hoffmann (1967) reports also blue, green, pink and brown crystals, dominantly cubic in habit but with octahedron and dodecahedron modifications not uncommon. The octahedral and dodecahedral development is seen especially in paler-colored fluorite, particularly pale pink, pale green and colorless, and much of the darker fluorite is coated with druses of descloizite and plattnerite (Hoffmann, 1967).

An occurrence on the first level of the Ojuela mine produced cubic crystals of pale blue fluorite partially enclosing wulfenite, barite and hemimorphite, and encrusted by colorless calcite which itself encloses small rosettes of aurichalcite, the whole assemblage sprinkled with microcrystals of plattnerite and murdochite (Hoffmann, 1967). No other good fluorite specimens seem to have appeared from the Ojuela mine from the 1960's until the early 1980's, when fluorite was found as bright bluish purple cubes to

Figure 85. **Fluorite crystal cluster on limestone, 12.5 cm, from the El Filo mine on La Reina Mountain, Mapimí district. Mike New specimen; Wendell Wilson photo.**

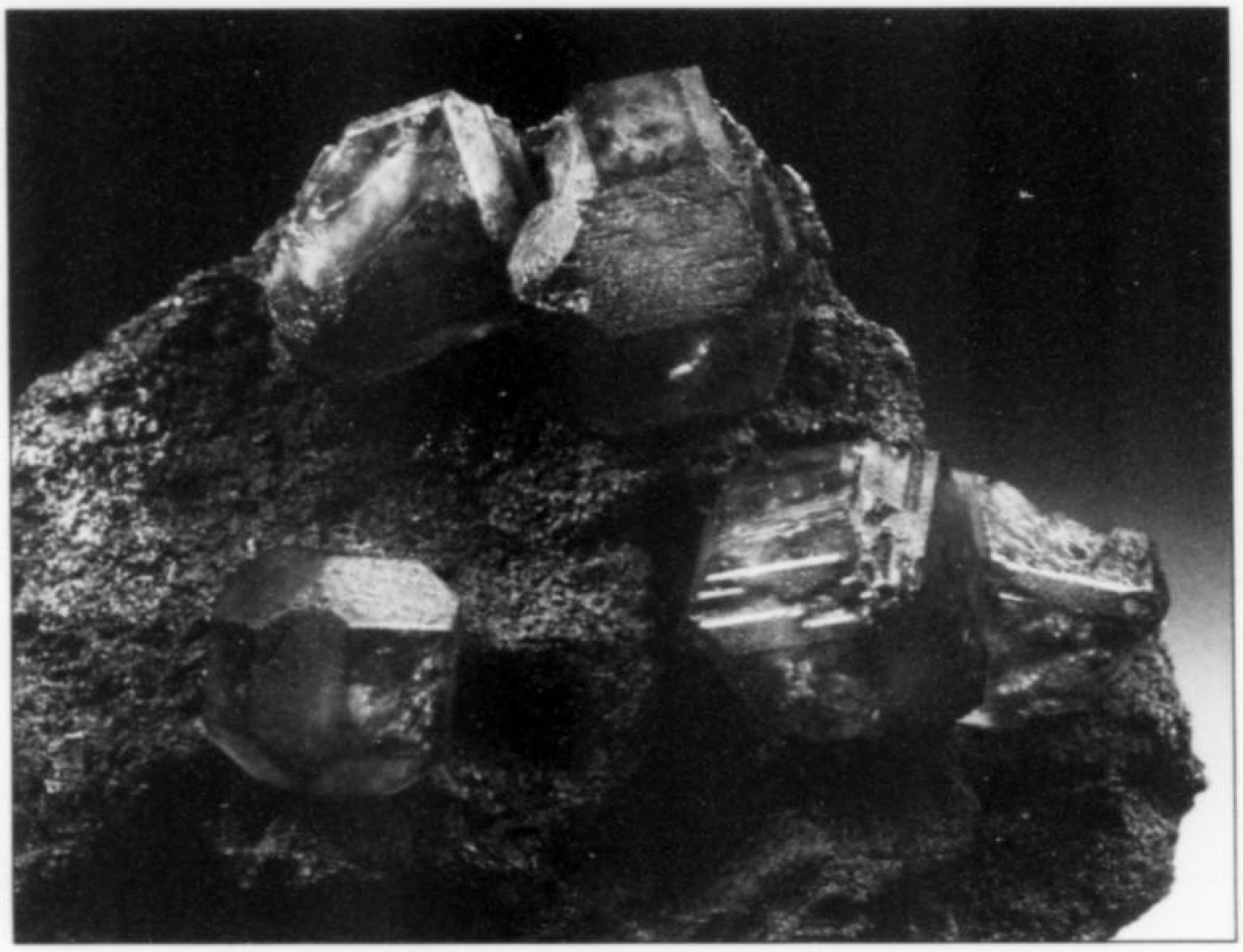


Figure 86. **Cubic-dodecahedral fluorite crystals to 1.4 cm from the Ojuela mine, "Manganeso"** ***lugar*****, Level 2 above the San Carlos adit. Terry Stambaugh collection; Wendell Wilson photo.**

2.5 cm, sometimes associated with malachite and olive-green wulfenite on barite crystals (Panczner, 1983a).

The *lugar* which the miners call "Manganeso," alternatively called *San Carlos*, Level 2, has produced what are probably the Ojuela mine's finest fluorite specimens. They are groups of deep purple cubes with beveling by dodecahedron faces, to 4 cm on edge individually, stacked in bar-shaped formations on a matrix of white barite with minor calcite and conichalcite; some of the fluorite crystals have pyrite inclusions.

Around 1988, good specimens with transparent pale violet cubic crystals of fluorite which fluoresce deep cherry-red under longwave ultraviolet light (Robbins, 1990) emerged in some abundance from a then-unspecified mine in the Mapimí district. A 1991 discovery on Level 2 in *La Esperanza* recalled by Manuel Lopez (personal communication, 2002) clearly represents the same occurrence as that mentioned by Robbins (Mike New, personal communication, 2003)—so this fluorescent fluorite too is from the Ojuela mine.

Elsewhere in the district there is one major locality for fine fluorite specimens—arguably, in fact, some of Mexico's finest. It is the **El Filo mine**, on La Reina Mountain, where fluorite crystals have been intermittently collected for the past 20 years. The purple cubes of El Filo fluorite can reach 4 cm on edge, and occur on siliceous limestone with drusy quartz (Mike New, personal communication, 2002). These crystals show concave, slightly rough faces and colorless-to-purple zoning, and thus resemble fluorite from the Elmwood mine, Tennessee; some crystals exhibit a beautiful spiraling pattern of growth features on their faces. In the spring of 1993, then again in 1999, 2001, and 2002, specimens of a bright purple fluorite on coarse-grained white quartz were recovered; they were reported to have been found in the Astillero mine, also on La Reina Mountain (Megaw, 1993), but undoubtedly they are from the El Filo mine (Peter Megaw, Mike New, personal communications, 2003).

Galena PbS

Galena is the main lead mineral of the district, and argentiferous galena orebodies yielded silver as well. Galena is found in pods up to several centimeters across, surrounded by alteration rinds of anglesite, cerussite, and other secondary lead minerals. In deeper, unoxidized zones the galena is finer-grained and is associated with sphalerite, pyrite, marcasite, chalcopyrite, arsenopyrite, enargite and tetrahedrite (Hoffmann, 1967). After the main phase of emplacement of the ore minerals, a later hydrothermal pulse deposited galena farther away, and specimens found in prospect pits peripheral to the main mineralization are associated with fluorite, barite, aurichalcite and calcite; small cubic galena crystals have been observed in these zones (Hoffmann, 1967). Some galena ore has a leaf-like texture; hence the name "Ojuela"—a derivation from "hojuela," meaning "leaflet" (Hoffmann, 1967).

Goethite α-Fe^{3+}O(OH)

Goethite, the most common iron mineral in the oxidized gossan zone, forms as an alteration product of pyrite, arsenopyrite, marcasite and pyrrhotite, and is the matrix for almost every secondary mineral assemblage in the Mapimí district (Hoffmann, 1967). In the Ojuela and **elsewhere in the district,** goethite varies from pale orange-brown, friable and vuggy masses to much denser, almost black botryoidal crusts and masses; the earthy goethite is much higher in the trace elements from which the rarer secondary species form. Pseudomorphs of goethite after pyrite crystals are common, and goethite pseudomorphs after arsenopyrite also occur. Siderite and ankerite may be coated with goethite, and hollow, rhombohedral casts of goethite after siderite crystals have been noted (Hoffmann, 1967).

Gold Au

Minute grains of gold are found in upper oxidized zones of the Ojuela mine and mines **elsewhere in the district**, associated exclusively with hematite, goethite and manganese oxides. Hoffmann (1967) found gold content in the primary ores to vary between less than 1 ppm and 8 ppm, the higher values being associated with pyrite in the more arsenical ores, suggesting that the pyrite or arsenopyrite is slightly auriferous.

Groutite Mn^{3+}O(OH)

Groutite is recognizable in polished ore sections as an alteration product of cryptomelane in manganese ores (Hoffmann, 1967).

Gypsum CaSO$_4$·2H$_2$O

Gypsum is a very late-stage mineral in the upper oxidized zones in most of the district's mines, found as cavity fillings in goethite and in calcite-lined vugs in the ore deposits and, more widely, as fillings in fractures in limestone and volcanic rocks. Between 1998 and 2000, hundreds of good gypsum/adamite specimens were taken from *San Juan Poniente* in the Ojuela mine, with gypsum ("selenite") crystals to 10 cm long. They are post-mining products, formed when water overflowed from a tarp stretched over a collecting area, then trickled down to form a pond on Level 6, dissolving sulfate and precipitating gypsum along its way (Mike New, personal communication, 2002). In the Ojuela mine, too, massive gypsum in small amounts is one of the "indicator" minerals for legrandite, having been found near the dramatic legrandite pockets in *Palomes Oriente-San Carlos.*

Elsewhere in the district, gypsum occurs sparingly with copper ores: rare euhedral crystals to 1 cm may contain inclusions of clay and native copper (Hoffmann, 1967). Panczner (1987) writes that at the end of 1983 a watercourse was discovered in "the upper areas of the Ojuela mine" which yielded etched, slightly frosted gypsum individuals and fishtail twins to 1 meter long, associated with goethite and copper; however, Mike New affirms from firsthand knowledge (personal communication, 2003) that the true locality for these specimens is the **Platosa mine**, north of Bermejillo—a mine with a history of producing fine "selenite," often associated with smithsonite, hydrozincite, and exceptional crystals of serpierite and schulenbergite.

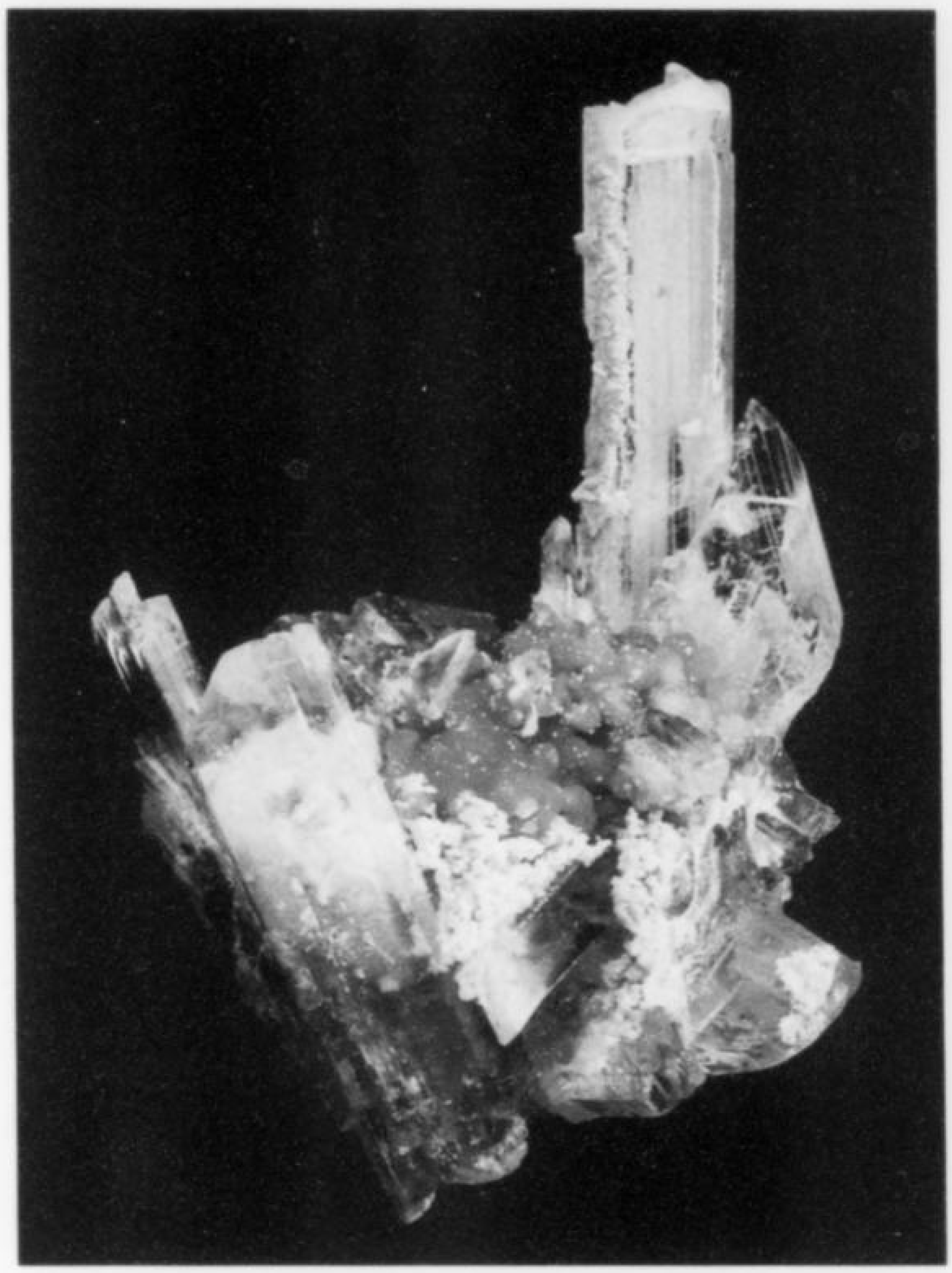


Figure 87. **Gypsum crystals with hydrozincite and aurichalcite (?), 7.3 cm, from the Platosa mine, Mapimí district. Kerith Graeber collection; Jeff Scovil photo.**

Around 1980, tabular gypsum crystals to 15 cm long with black phantoms were collected in the **Platosa mine**: these came from a gypsum cave encountered in the mine workings, where sword-shaped crystals to almost 2 meters lined the walls. Some of the gypsum crystal groups are partially encrusted by gray to blue "rice grain" smithsonite crystals, and by white crusts of hydrozincite (Mike New, personal communication, 2002).

Hausmannite Mn^{2+}Mn$_2^{3+}$O$_4$

Hausmannite has been noted in polished sections of manganese ores from *America Dos* and from *San Juan Poniente*; it is associated with and altered from cryptomelane and pyrolusite (Hoffmann, 1967).

Hedyphane Pb$_3$Ca$_2$(AsO$_4$)$_3$Cl

Translucent white crystals of hedyphane to 4 mm with mimetite and bindheimite have come from *San Juan Poniente* (Hoffmann, 1967; Panczner, 1987). The species was identified by Hoffmann (1967) through X-ray diffraction studies of the material in comparison with mimetite from Mapimí and hedyphane from Franklin, New Jersey.

Hematite Fe$_2$O$_3$

Minor occurrences of hematite have been noted in the Ojuela

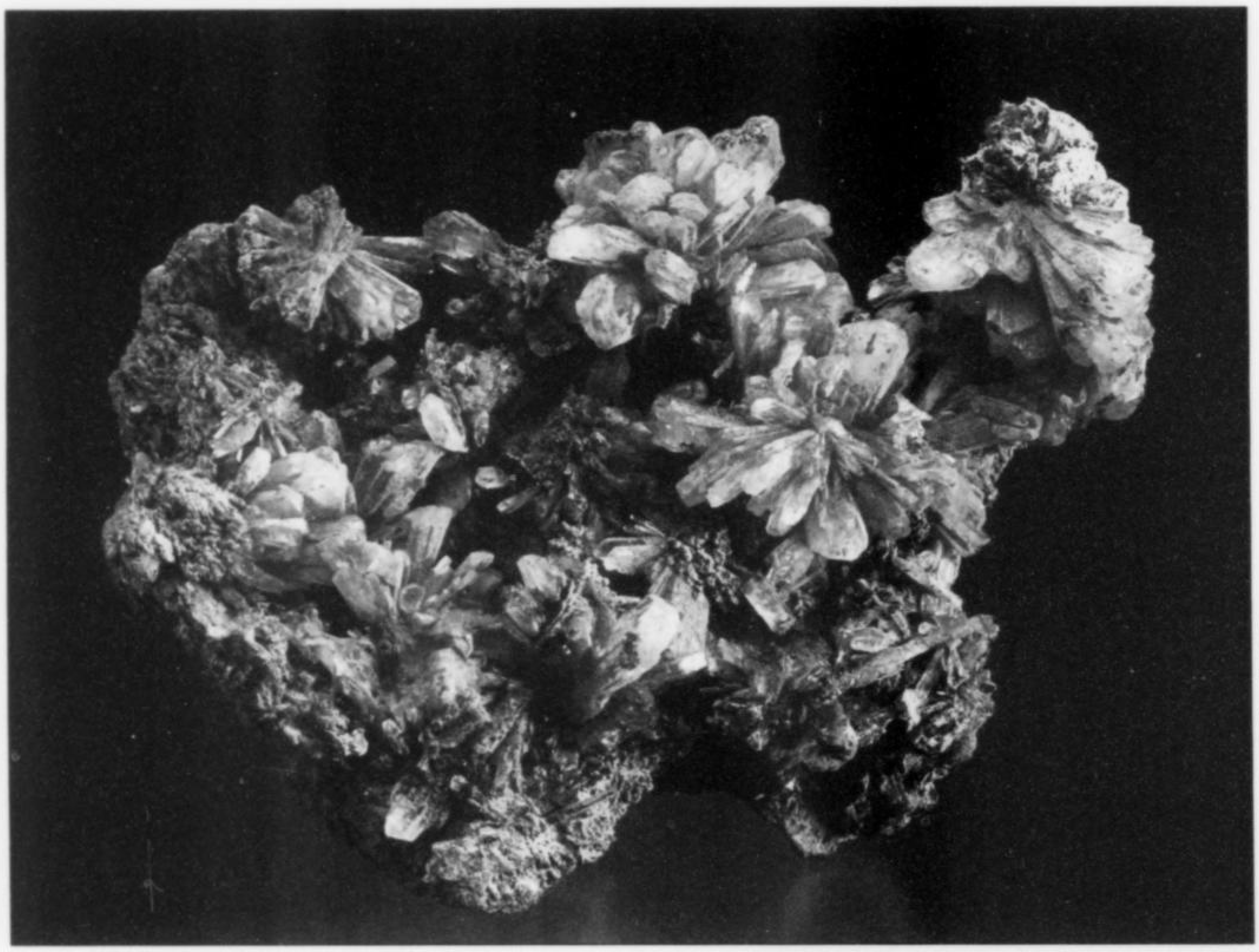


Figure 88. **Hemimorphie with aurichalcite on limonite, 6.3 cm, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

Figure 89. **Hemimorphite crystals to 2 cm, from the Ojuela mine. Thomas Moore collection; Wendell Wilson photo.**

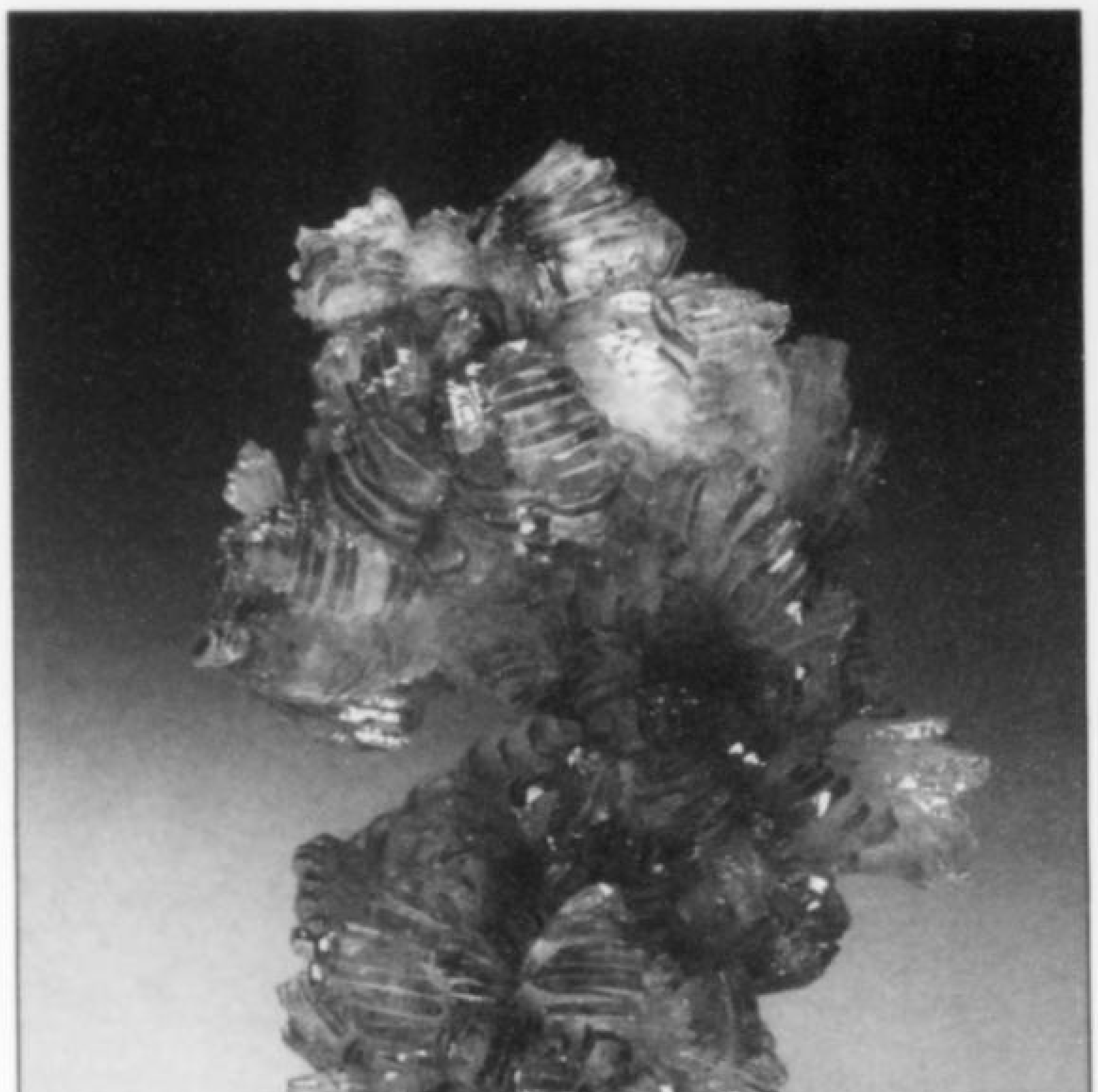


Figure 90. **Hemimorphite crystal cluster, 9.5 cm, from the Ojuela mine. John Whitmire specimen (1983); Wendell Wilson photo.**

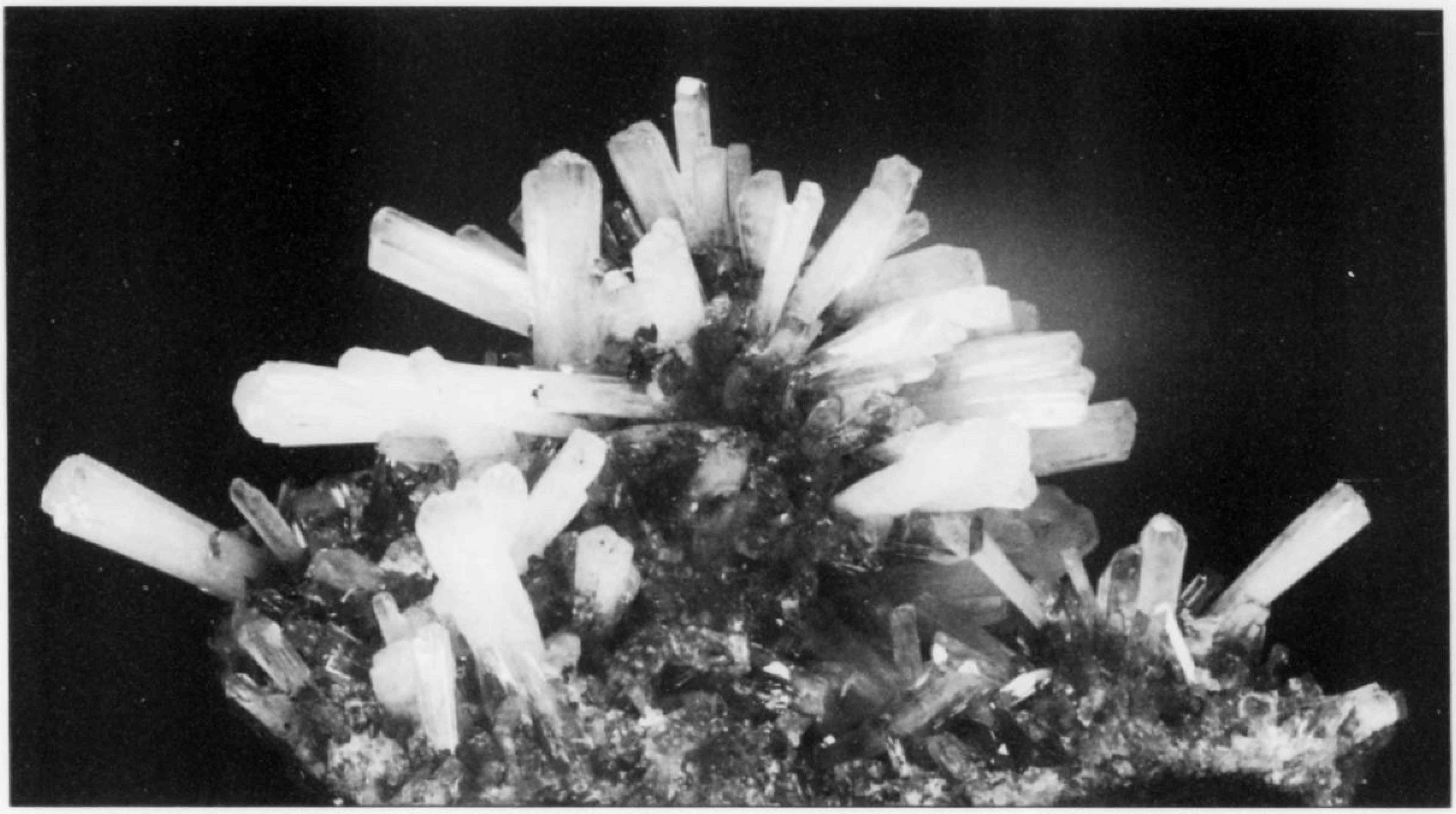


Figure 91. **Hemimorphite crystals on matrix, 12.8 cm, from the Ojuela mine. Pat Hendrick collection; Jeff Scovil photo.**

mine, where it is associated with the much more common iron oxide goethite, and with copper minerals; no hematite crystals have been recorded.

Elsewhere in the district, hematite is the main constituent of the iron ores of the **La Lucha mine** near Dinamita, where it is found as large red masses near the contact between the Sarnoso Stock and limestone (Hoffmann, 1967).

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Specimen-quality hemimorphite has always been found fairly abundantly in the Ojuela mine, where it occurs as a late-stage mineral in all oxidized zones of the deposit, from almost at the surface to just above the water table in the lower levels (Panczner, 1987). Colorless to snow-white, commonly very lustrous prismatic crystals and sheaflike aggregates of subparallel crystals reach 3 or 4 cm in length (Hoffmann, 1967; Bancroft, 1984); these can form aesthetically pleasing sprays on dark brown goethite matrix, or "bow-tie" formations composed of two crossing sheaves (Jones, 1970b). Hemimorphite crystals invariably occur on goethite (and are sometimes stained brown or yellow by it); associations, where present, include calcite, aurichalcite, rosasite and adamite. Colorless hemimorphite is sometimes seen as a coating on lath-like crystals and sprays of aurichalcite (Jones, 1970b), and encrusting cigar-shaped formations of goethite (Johnson, 1962).

Jones (1970b) commented on the relative abundance of fine Ojuela mine hemimorphite specimens on the mineral market, saluting the showy specimens with 8-cm crystals which were available at the 1970 Tucson Show. Since that time, however, new examples of this beautiful material have been largely absent from the market, and it is in general less well known than it deserves to be. The lustrous white sheaves of hemimorphite on goethite from Mapimí should not be confused with the bladed, hematite-stained white crystals from the Santa Eulalia district in Chihuahua which began to appear on the market in the early 1970's (White, 1971).

In general, *San Carlos* has been a good but sporadic source of excellent hemimorphite specimens. In 2001, between Levels 5 and 6, *San Judas* produced about 50 specimens representing some of the very best hemimorphite ever found in the Ojuela mine: deep vugs in goethite and flat matrix plates to 45 cm are covered with sprays, spheres and wheels of white, lustrous crystals to 5 cm individually. An extraordinary large cabinet specimen from this occurrence is in the Peter Megaw collection.

"Higginsite" See **Conichalcite–Austinite**

"Hydrohausmannite"

Hoffmann (1967) described "hydrohausmannite" as occurring in grains and thin bands in the manganese ores of the district. This substance has subsequently proven to be a mixture of hausmannite and feitknechtite (Bayliss, 2000).

Hydrohetaerolite $Zn_2Mn^{3+}_4O_8 \cdot H_2O$

Hydrohetaerolite forms elongated euhedral crystals to 8 mm in fractures in manganese ore, and masses of euhedral grains replacing cryptomelane (Hoffmann, 1967; Panczner, 1987). It is relatively common in the manganese ore of *America Dos* and *San Juan Poniente* in the Ojuela mine (Hoffmann, 1967).

Hydrous sulfates

Hoffmann (1967) sampled and analyzed white to pale bluish white efflorescences found near water seepages, as well as efflorescent sulfate deposits on limestone, frequently with gypsum, at many sites in the Mapimí district. He found the species involved to be hexahydrite, bianchite, epsomite, goslarite, pickeringite and halotrichite; these have crystallized as post-mining products.

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

Hydrozincite, an alteration product of aurichalcite and other zinc minerals, was common in high-zinc areas of the oxidized zones in the Ojuela mine, associated with hemimorphite, aurichalcite and plattnerite (Hoffmann, 1967). White coatings and fibrous layers of hydrozincite, perhaps mixed with sauconite, reached considerable thickness in some cavities in goethite (Jones, 1970b). Although hydrozincite alters from aurichalchite, and their formulas are the same except for partial substitution of copper for zinc in aurichalchite, the two species do not form a solid solution series; hydrozincite does not contain significant copper (Jambor and Pouliot, 1965). The white hydrozincite coatings on goethite are fluorescent a brilliant blue in shortwave ultraviolet light.

Encountered at other localities as a massive, chalky white, uninteresting species, hydrozincite from the Ojuela mine has considerable collector appeal because of its fluorescence, and even more so because it is (for the species) remarkably well crystallized. Delicate white acicular crystals frequently form solid blankets on white massive hydrozincite lining goethite vugs; individual crystals reach 4 mm, and are well terminated (Jones, 1970b). Specimen material came out abundantly around 1960, but had stopped appearing on the market by about 1970 (Jones, 1970b). Large specimens consisting of plates of fuzzy white microcrystals with plattnerite were found during the 1960's in *America Poniente*.

Elsewhere in the district, white crusts of hydrozincite are found, with "rice grain" crystals of smithsonite, on large gypsum crystals in the **Platosa mine**.

Jamesonite $Pb_4FeSb_6S_{14}$

Jamesonite replaces boulangerite along fractures and grain boundaries in district ores, and is seen to have altered in turn to bindheimite (Hoffmann, 1967). There exist a few specimens showing metallic hairlike crystals of jamesonite to 3 cm long on massive to crudely crystallized pyrite; these are sometimes said to have come from the Ojuela mine (Stambaugh, 2002), but in fact are from Noche Buena or San Martín, Zacatecas (Mike New, personal communication, 2003).

Jarosite $K_2Fe_6^{3+}(SO_4)_4(OH)_{12}$

In the Mapimí district generally, jarosite is usually found as large, pulverulent yellow masses in the upper oxidized portions of orebodies, associated with bindheimite, mimetite and goethite. Hoffmann (1967) found that varying optical properties in the massive material correspond to wide variations in trace lead content, and that the jarosite contains many other trace metals as well, having altered from pyrite in the presence of galena, bournonite and other sulfides. Transparent, euhedral, golden brown crystals of jarosite to 4 mm on botryoidal goethite have been found (Hoffmann, 1967; Panczner, 1987), but these are not necessarily from the Ojuela mine.

Kaolinite $Al_2Si_2O_5(OH)_4$

Kaolinite, associated with manganese and iron oxides, occurs in veinlets and fault gouge areas in upper oxidized zones in district mines (Hoffmann, 1967).

Köttigite-Parasymplesite $Zn_3(AsO_4)_2 \cdot 8H_2O–Fe_3^{2+}(AsO_4)_2 \cdot 8H_2O$

Köttigite is a very rare mineral which has occasionally been found in dramatic, high-quality specimens in the Ojuela mine, in opaque sprays of lustrous, grayish blue, acicular crystals to 6 cm on goethite matrix. Except for its color it resembles legrandite, and is found in the same general areas of the mine; consequently the miners call it "blue legrandite" (Panczner, 1984). Probably the nickname is meant to allude as much to its great value and desirability for collectors as to its appearance.

A complete series exists between köttigite and parasymplesite, with all intermediate members present in the Ojuela mine, perhaps even within compositional zones of single crystals (White, 1976). The type locality for köttigite is Schneeberg, Obersachsen, Germany, where the crystals are pale to dark red (because, according to Paul Desautels, they are a cobaltian variety: White, 1976). X-ray crystallographic studies and microprobe analyses of chemical compositions have shown the Schneeberg material to be relatively pure end-member köttigite, whereas the Ojuela mine "köttigite" is,

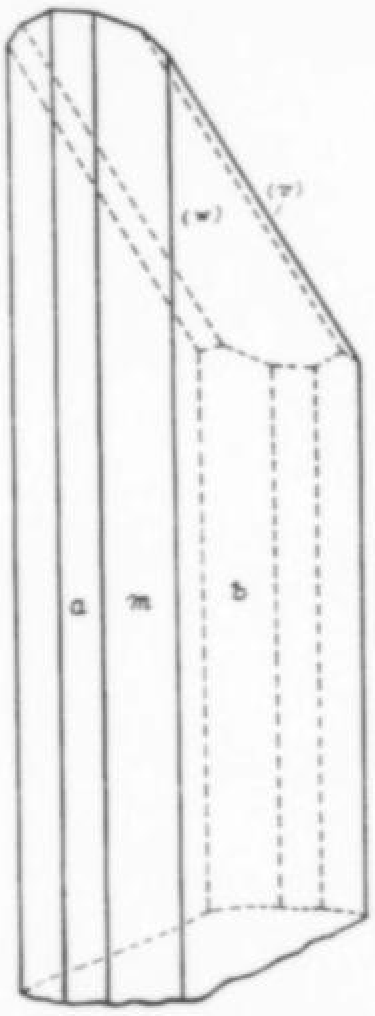


Figure 92. **Parasymplesite crystal drawing, Ojuela mine. Forms: *a*{100}, *b*{010}, *w*{201}, *v*{221} (Sturman, 1987).**

Figure 93. **Köttigite crystals, 5.3 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.**

Figure 94. **Parasymplesite crystals to 7 mm on limonite, 3.5 cm, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

in general, intermediate in composition between ideal köttigite and parasymplesite, with the best of the Ojuela specimens studied actually being on the parasymplesite side of the series (Sturman, 1976). It would seem best to follow John White's advice that collectors label the Ojuela specimens "köttigite/parasymplesite" in all cases (White, 1976).

First mentioned in the literature by Larsen (1921), parasymplesite from the Ojuela mine first caught the eye of collectors and curators in the mid-1960's (Desautels, in White, 1976), and specimens of the "blue legrandite" would occasionally turn up, e.g. in the shop of American mineral dealer George Griffith in Gomez Palacio (Miller and Olson, 1970). Small sprays of crystals were found in pockets near to—but never in—the purple adamite pockets of 1981 in *San Judas*. Otherwise, köttigite/parasymplesite is associated with legrandite; in fact, the assemblage köttigite/parasymplesite-gypsum-smithsonite is regarded as an indicator that legrandite pockets are nearby. Good köttigite/parasymplesite crystal sprays were collected with the legrandite of *Palomes Oriente* during the late 1960's and early 1970's; in 1974 a major pocket was found here, with blue acicular köttigite/parasymplesite crystals to 6 cm associated with gypsum, smithsonite, and legrandite. The dry season had lowered the water table just enough to expose the pocket (Panczner, 1987), and many examples collected here have a dull coating resulting from repeated immersions (Barlow and Juneau in Barlow, 1996). Specimens from this major find were purchased and brought to the mineral market by Benny Fenn (Panczner, 1984), and there have been no comparable finds since; köttigite/parasymplesite from Ojuela remains a "classic" that is extremely difficult to acquire in fine specimens.

Legrandite $Zn_2(AsO_4)(OH){\cdot}H_2O$

Legrandite is a rare and very beautiful zinc arsenate which has been found as high in the Ojuela mine as Level 3 and as low as Level 6, but the best specimens are from Level 5, in the lowermost part of the oxidized zone, where the fluctuation of the water table in response to seasonal variations in rainfall alternately floods and exposes the crystal pockets (Panczner, 1987, refers to this region as "Levels 12, 13 and 17," but this reflects the old numbering system). Ojuela legrandite is famous for its high luster and brilliant yellow to yellow-orange color; a very few transparent, gemmy crystals have even been found (Sinkankas, 1970), and two or three have been cut into faceted gems (see sidebar, "A Fortuitous Trade"). Periodic discoveries of bonanza pockets of lustrous yellow legrandite crystals have electrified the mineral market at intervals for the last

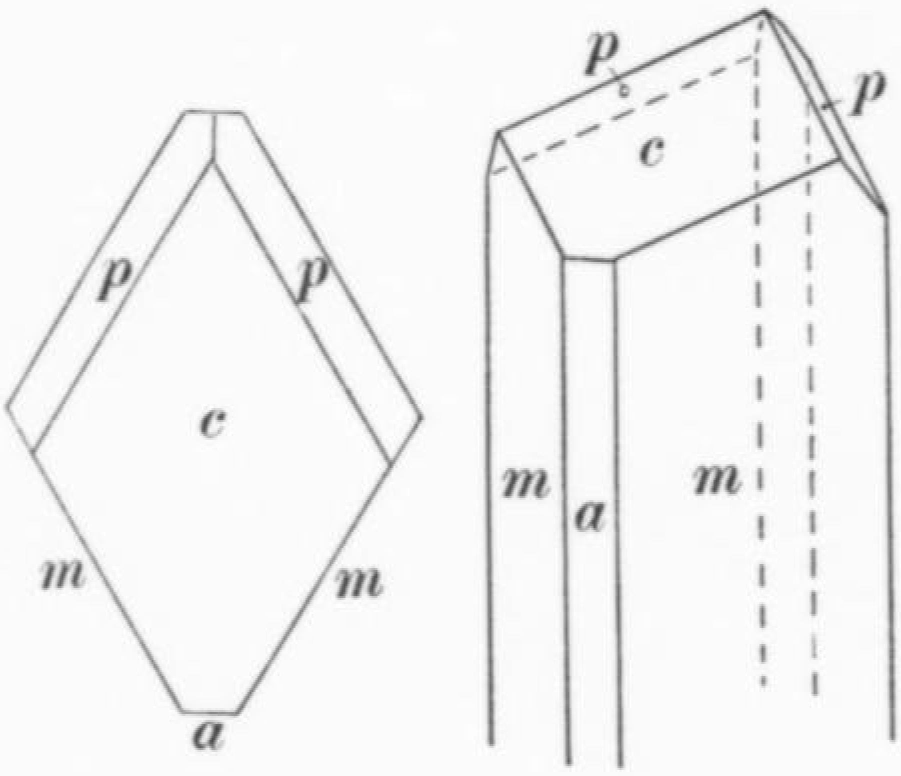


Figure 95. **Legrandite crystal drawings based on specimens from the type locality, the Flor de Pena mine. Forms: *a*{100}, *m*{110}, *c*{001}, *p*{$\bar{1}$11} (Drugman and Hey, 1932).**

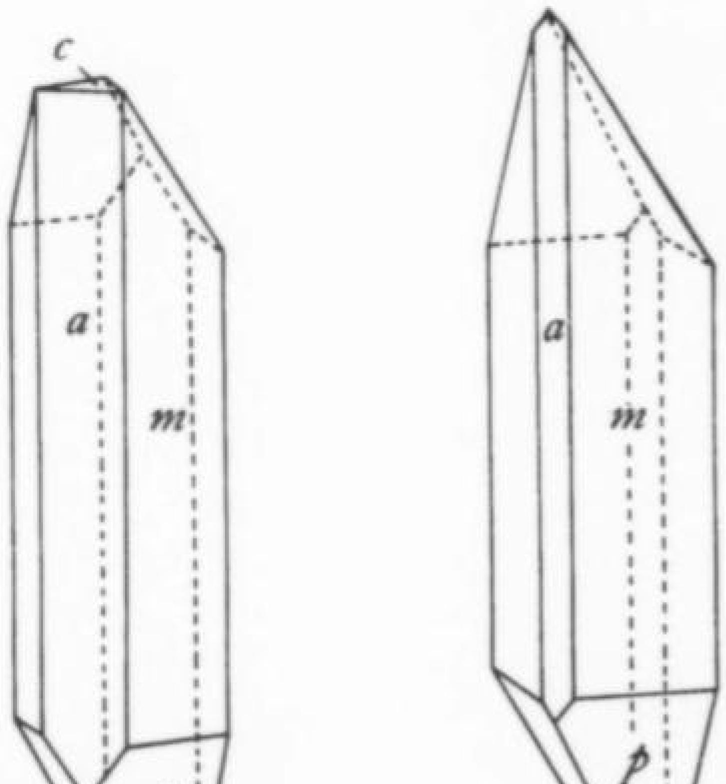


Figure 96. **Legrandite crystal drawings, Ojuela mine. Forms: *c*{001}, *a*{100}, *m*{110}, *p*{$\bar{1}$11} (Desautels and Clarke, 1963).**

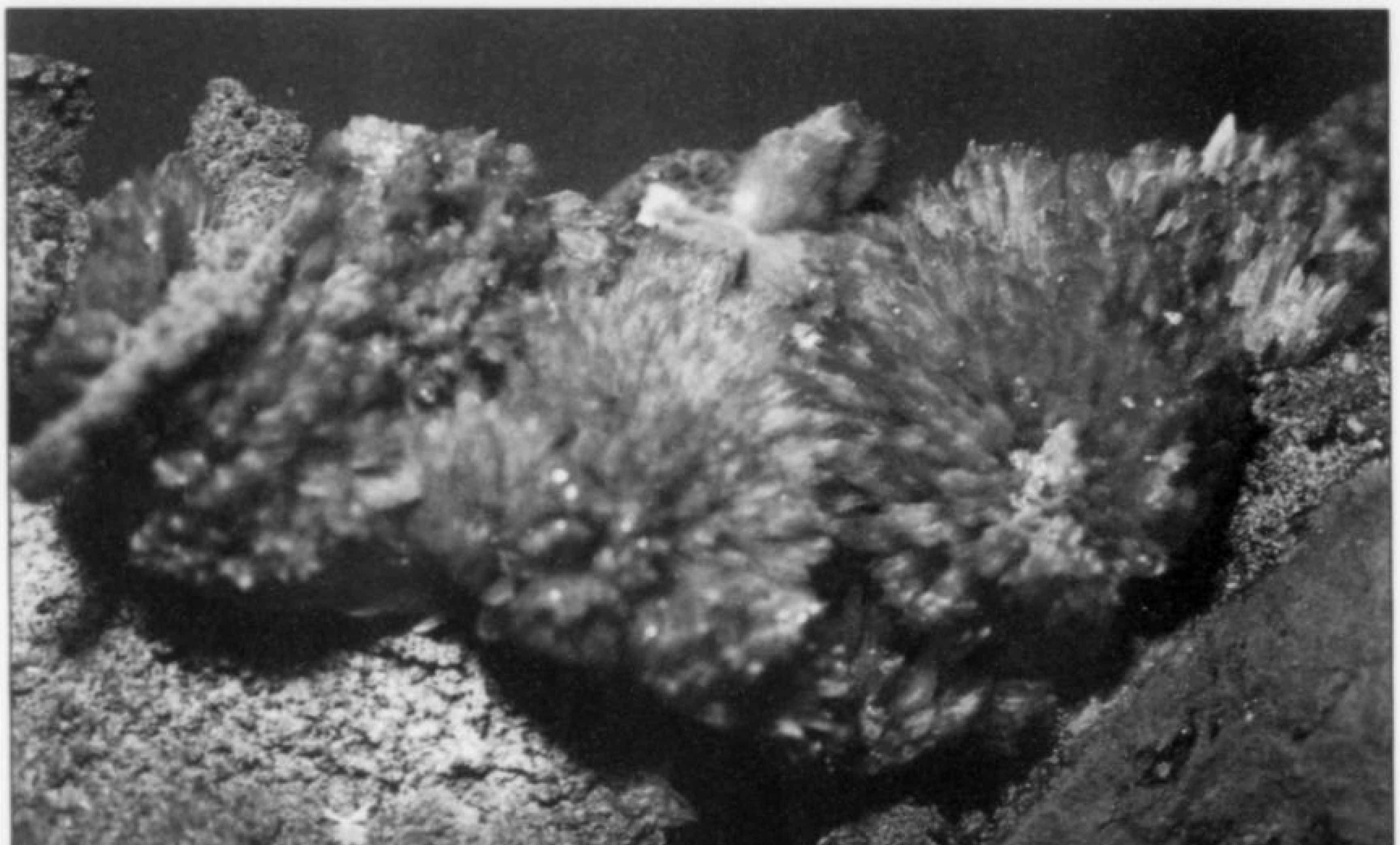


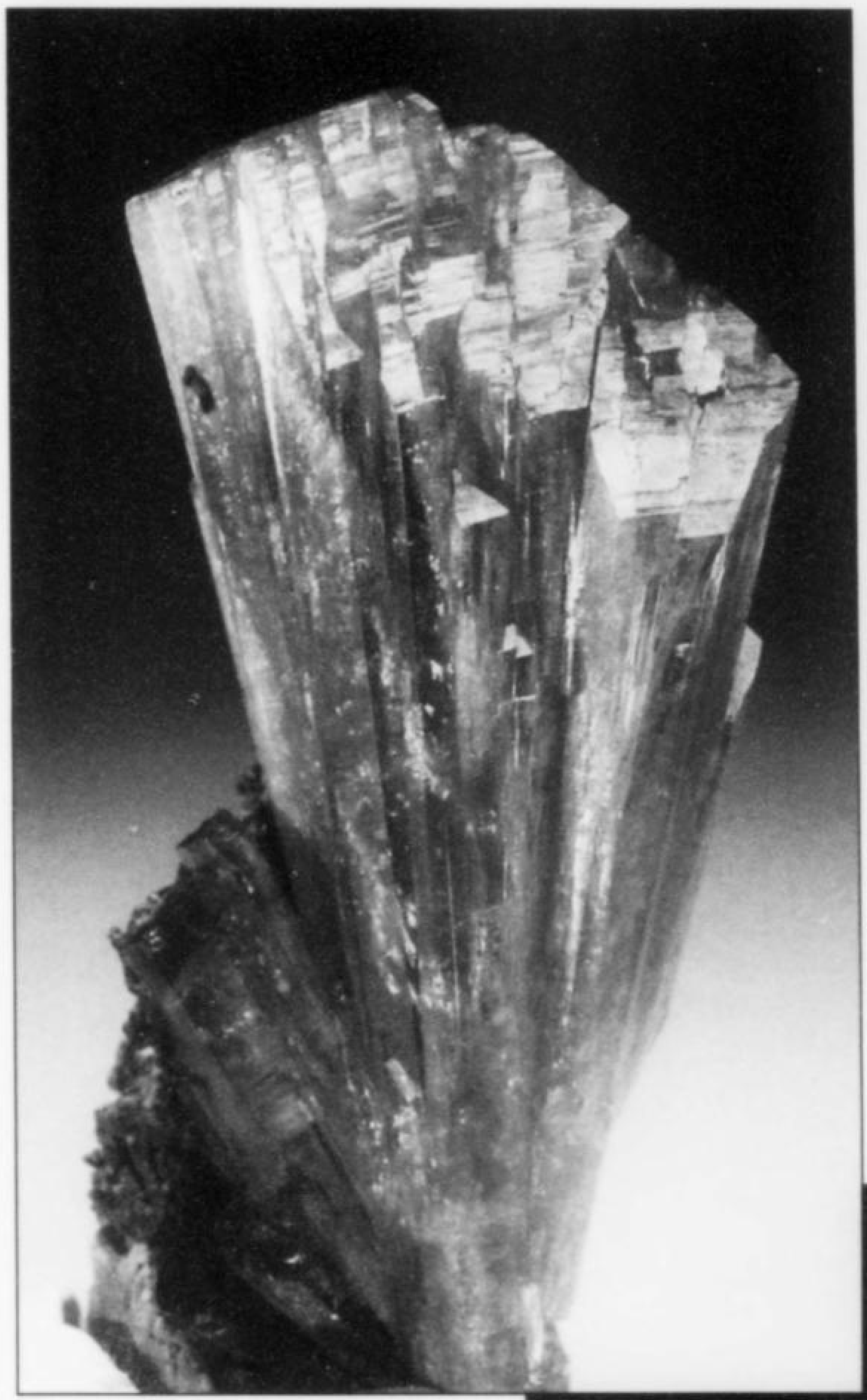
Figure 97. **Legrandite crystals to 2.5 cm on limonite matrix, from the Ojuela mine. Smithsonian Institution specimen (1976); Wendell Wilson photo.**

Figure 98. **Large sprays of acicular legrandite, 16 cm, on limonite matrix, from the Ojuela mine. Smithsonian Institution specimen (1976); Wendell Wilson photo.**

50 years. Until a pocket of exceptionally fine legrandite crystals (six superior specimens with terminated crystals to 2.5 cm) was found in the lowest workings of the Tsumeb mine, Namibia just before that mine's final closure in 1997 (Gebhard, 1999), the Ojuela mine was the world's only well-known source of connoisseur-quality legrandite specimens.

The type locality for legrandite, however, is not the Ojuela but rather the relatively obscure Flor de Pena mine, Lampazos, Nuevo Leon, Mexico, from whence it was described in 1932; the name is for a Monsieur Legrand, the Belgian mine manager at the Flor de Pena (Drugman and Hey, 1932). Crystals from this locality reach a surprising 4 cm (Panczner, 1987), but were never common, and never reached the specimen market in any significant numbers. (They have all come from the dumps; an underground specimen-recovery effort may soon get underway, so that more and better Flor de Pena legrandite specimens may be hoped for—Peter Megaw, personal communication, 2003.)

In 1963 the slightly incorrect chemical composition given in



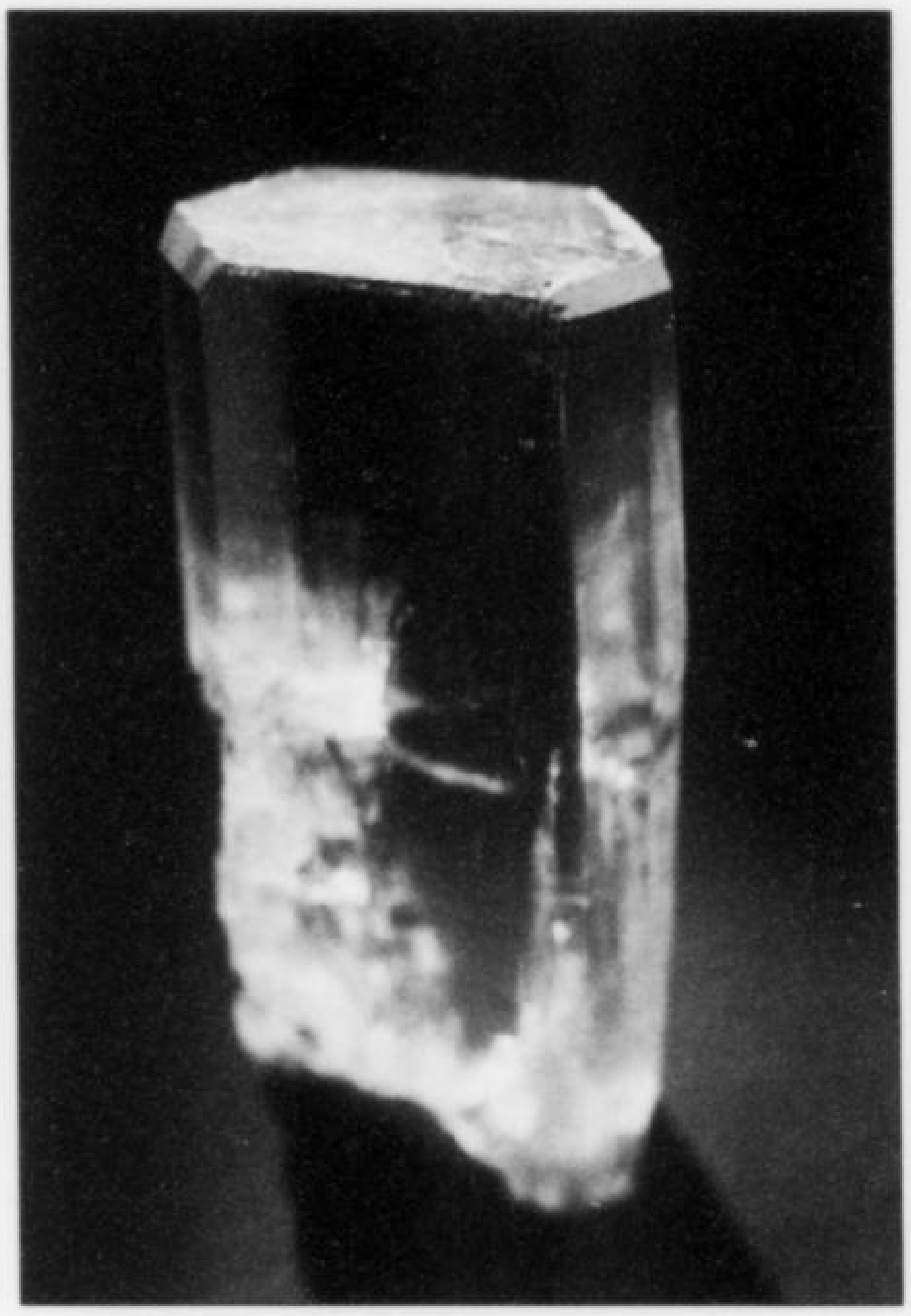


Figure 100. **Gem-grade legrandite crystal, 1.2 cm, from the Ojuela mine. Smithsonite Institution specimen (1972); Wendell Wilson photo.**

Figure 99. **Large divergent cluster of legrandite crystals, 4.7 cm, from the Ojuela mine. Miguel Romero collection, now in the University of Arizona Mineral Museum; Wendell Wilson photo.**

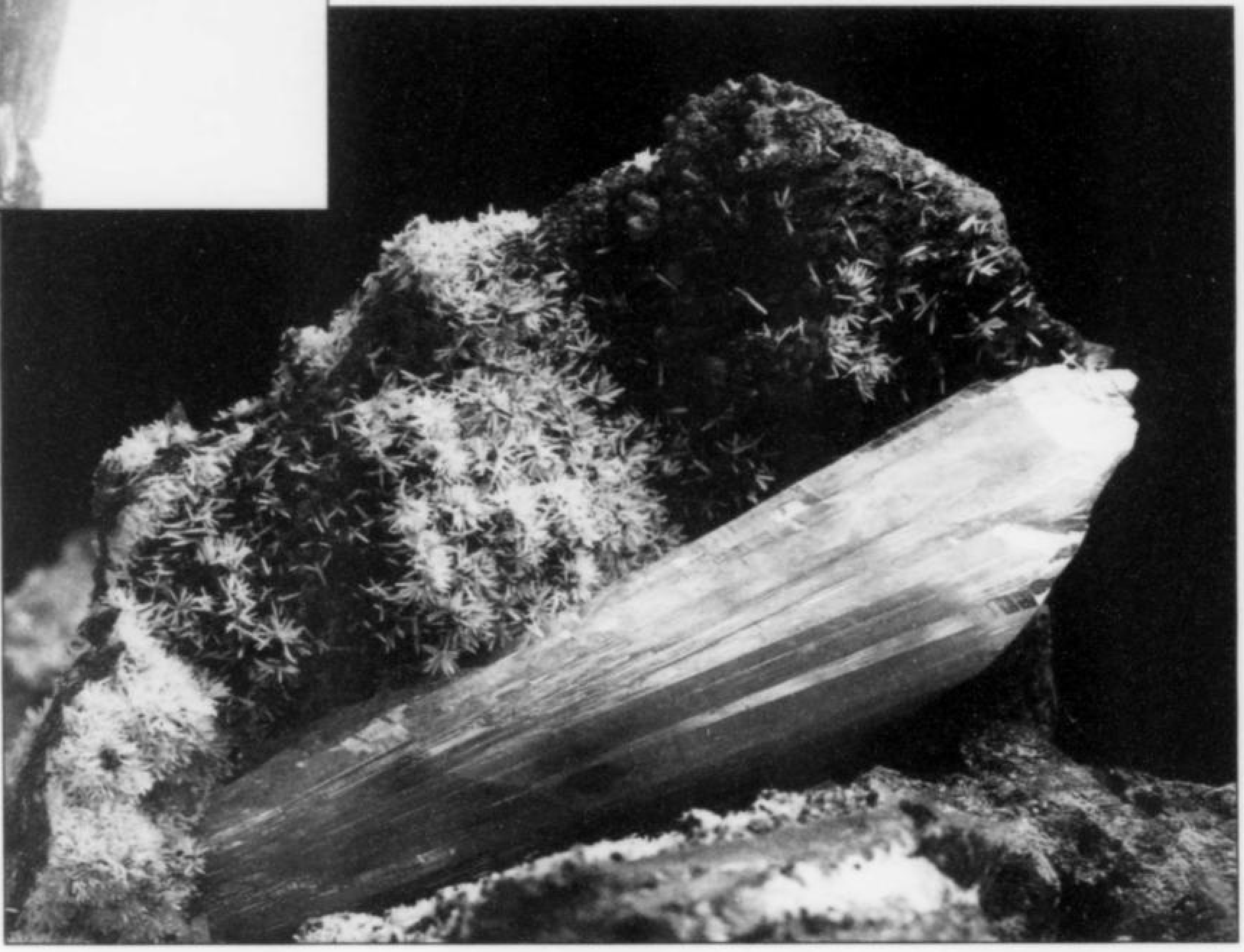


Figure 101. **Legrandite crystal, 7.5 cm, on limonite with hydrozincite (?), from the Ojuela mine. Harvard Mineralogical Museum collection; Wendell Wilson photo.**

1932 was corrected, and the space group determined (Finney, 1963; Desautels and Clarke, 1963). Further work showed an unusual structure consisting of tetrahedrally co-ordinated arsenate groups in an undulating chain parallel to the *a* axis, with arsenate tetrahedra sharing apices with zinc polyhedra (McLean *et al.*, 1971).

The monoclinic legrandite crystals are long-prismatic, elongated parallel to [001]; many isolated single crystals, including doubly terminated ones, have been found in the Ojuela mine, but the most common habit is as sprays, fans, and sheaf-like subparallel groups. The crystals occur on hard brown goethite ("limonite") matrix, with other rare arsenates and with köttigite/parasymplesite, gypsum, smithsonite and jarosite; some crystals are etched or partially altered to a dark yellow-brown, lusterless material, probably as a result of the repeated immersions as the water table fluctuated (Jones, 1971b).

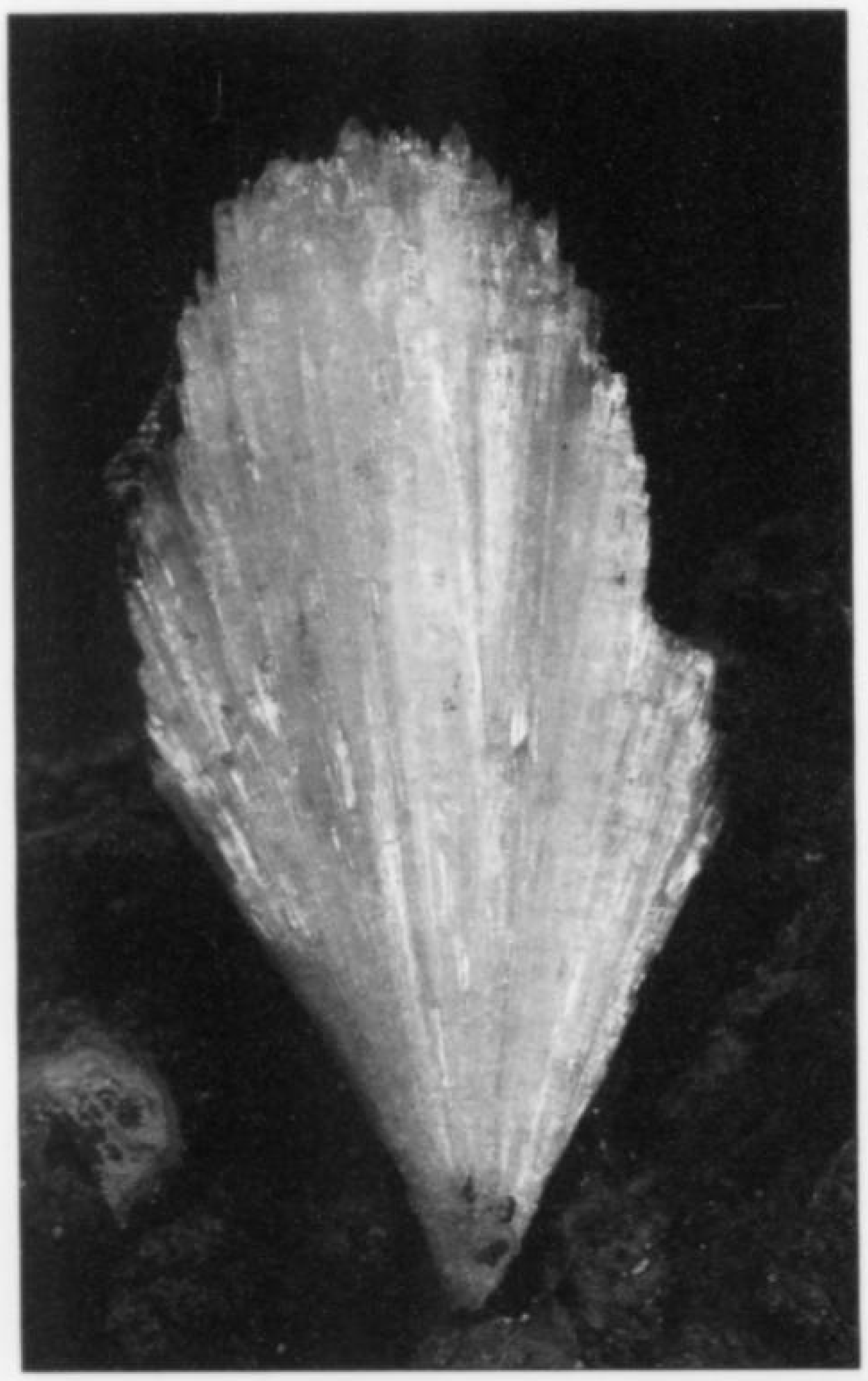


Figure 102.(left) **Legrandite crystal spray, 4 cm, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

Figure 103. (right) **Huge legrandite crystal spray, known as the "Aztec Club," 14 cm, from the Ojuela mine, San Juan Poniente stope, Level 5. Collected in 1977 by Felix Esquivel. American Museum of Natural History collection; Wendell Wilson photo.**

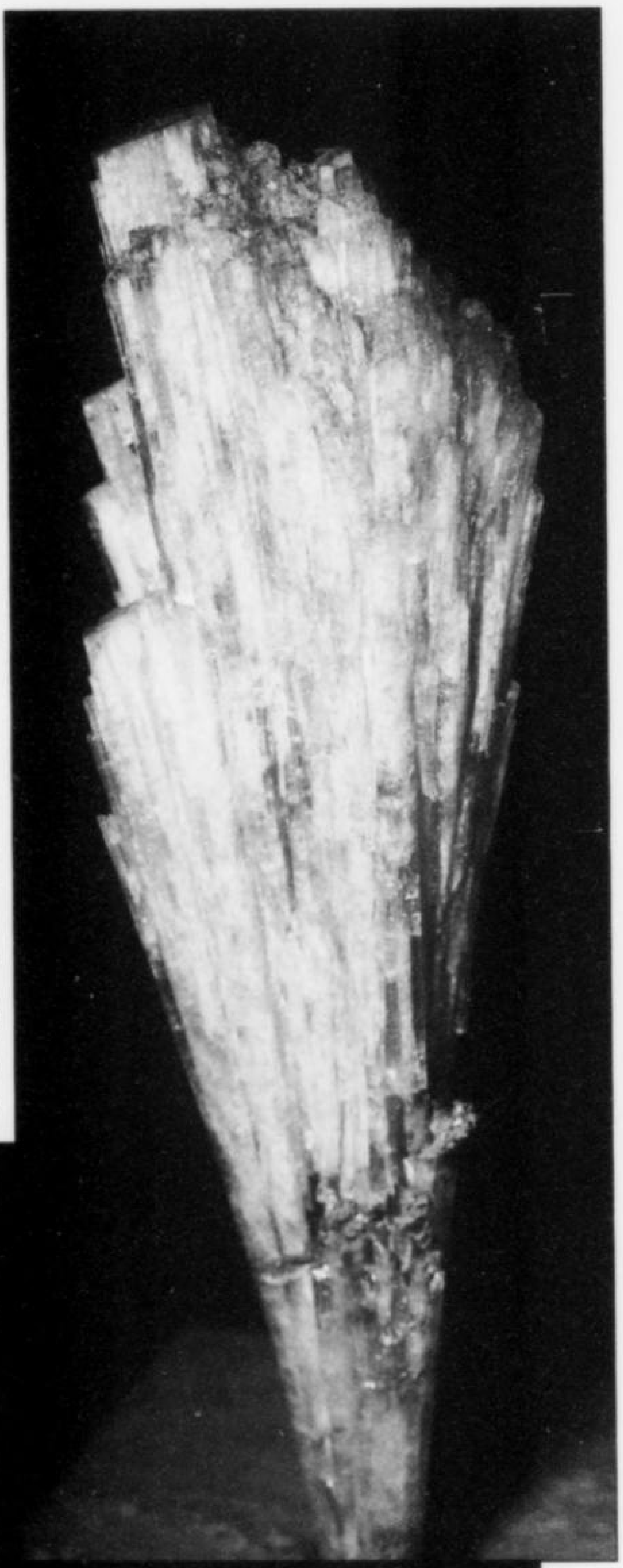
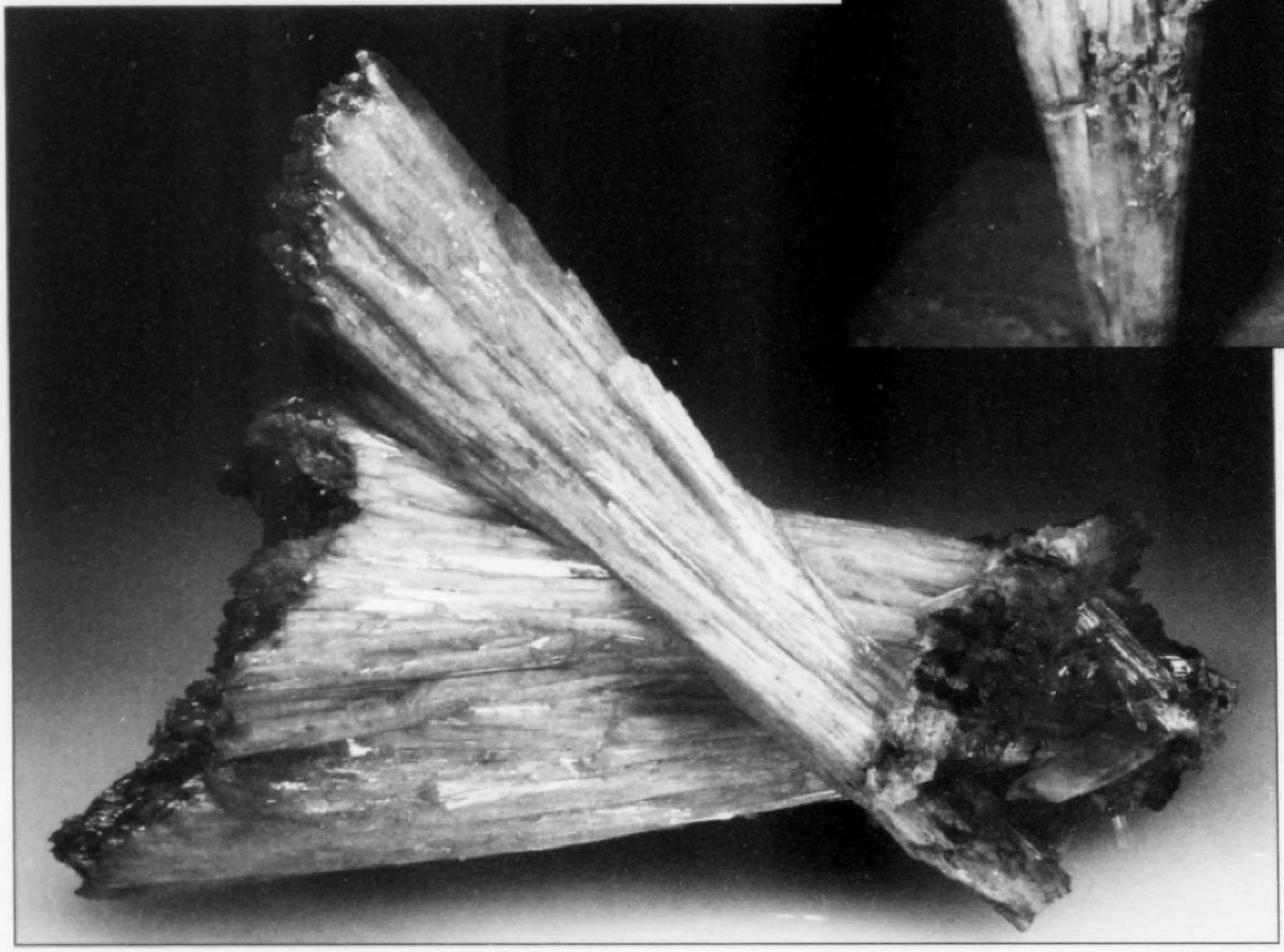


Figure 104.(below) **Huge legrandite crystal cluster, known as the "Aztec Sun," 17.2 cm, from the Ojuela mine, San Juan Poniente stope, Level 5. Collected in 1977 by Felix Esquivel. Miguel Romero collection, now in the University of Arizona Mineral Museum; Wendell Wilson photo.**



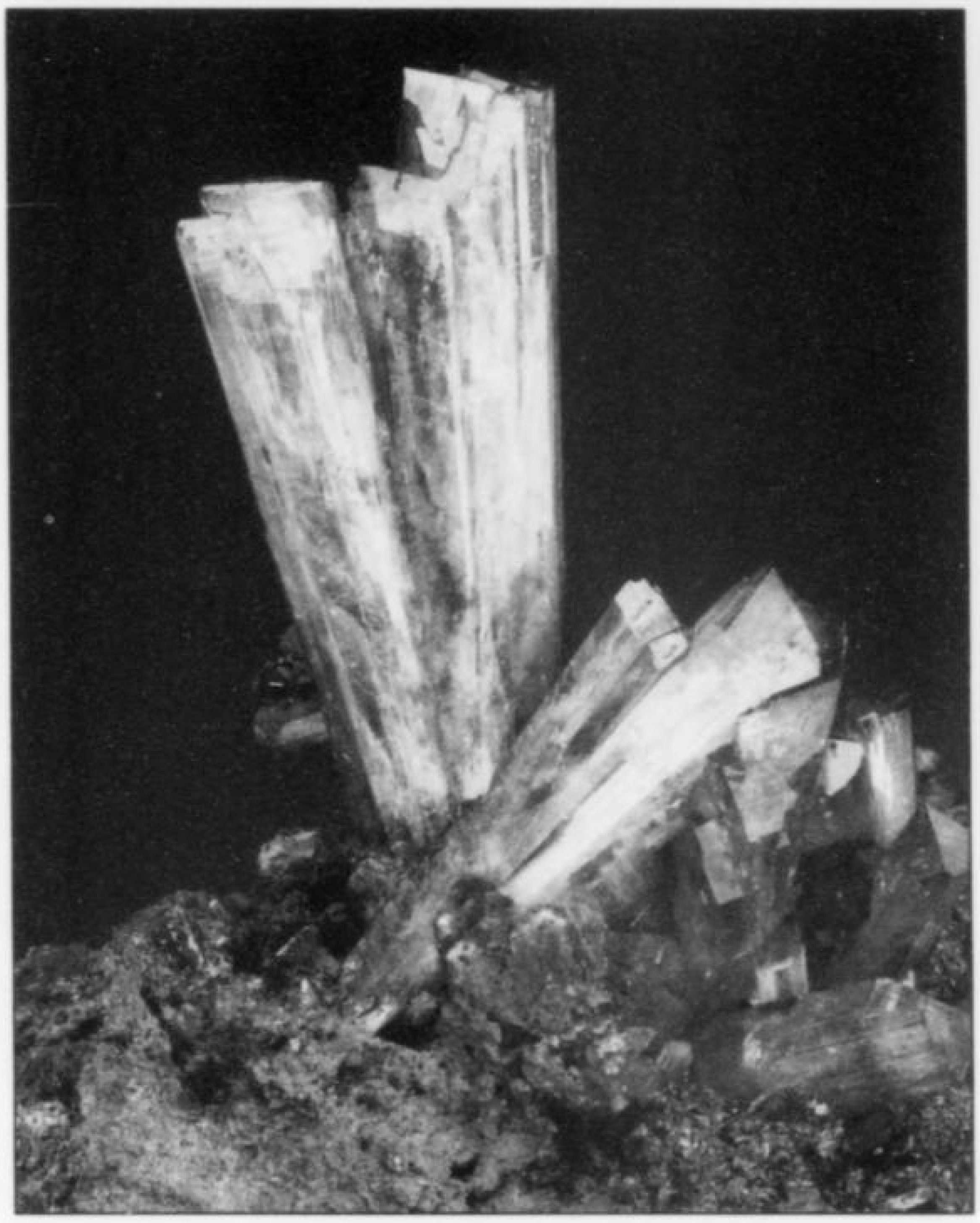


Figure 106. **Legrandite crystals to 3.1 cm on limonite, from the Ojuela mine. Richard Jackson collection; Jeff Scovil photo.**

Figure 105. **Legrandite crystal pocket in limonite, 15 cm across, from the Ojuela mine. Rice Northwest Museum of Rocks and Minerals collection; Bob Jones photo.**

Figure 107. **Doubly terminated legrandite thumbnail, 2.9 cm, from the Ojuela mine. Ralph Clark collection; Wendell Wilson photo.**

The saga of major legrandite pocket discoveries excites the imagination. The first significant specimen material was found during the early 1950's by collector/dealer George Griffith, who just managed to get the beautiful yellow crystals identified as legrandite before the productive workings were flooded again; in the late 1950's Arizona mineral dealer Scott Williams sold the few specimens Griffith had found, consisting of glassy acicular sprays of crystals on earthy, pale to dark brown matrix (Jones, 1971b). In 1961 and 1962, Griffith returned to the area of the earlier finds—probably the area called *Los Changos* (see below)—and collected large numbers of fine specimens with elongated crystals, many of them doubly terminated, to 6 cm (Hoffmann, 1967; Jones, 1971b). In 1965 a major pocket yielded sprays with crystals to 5 cm long, and bright yellow individuals to 10 cm (Panczner, 1987).

The written record is unclear, but in all probability the early pockets mentioned above were on Level 5 between *Palomes Oriente* and *San Carlos*, where legrandite continued to be found intermittently from the late 1960's through the mid-1970's. In

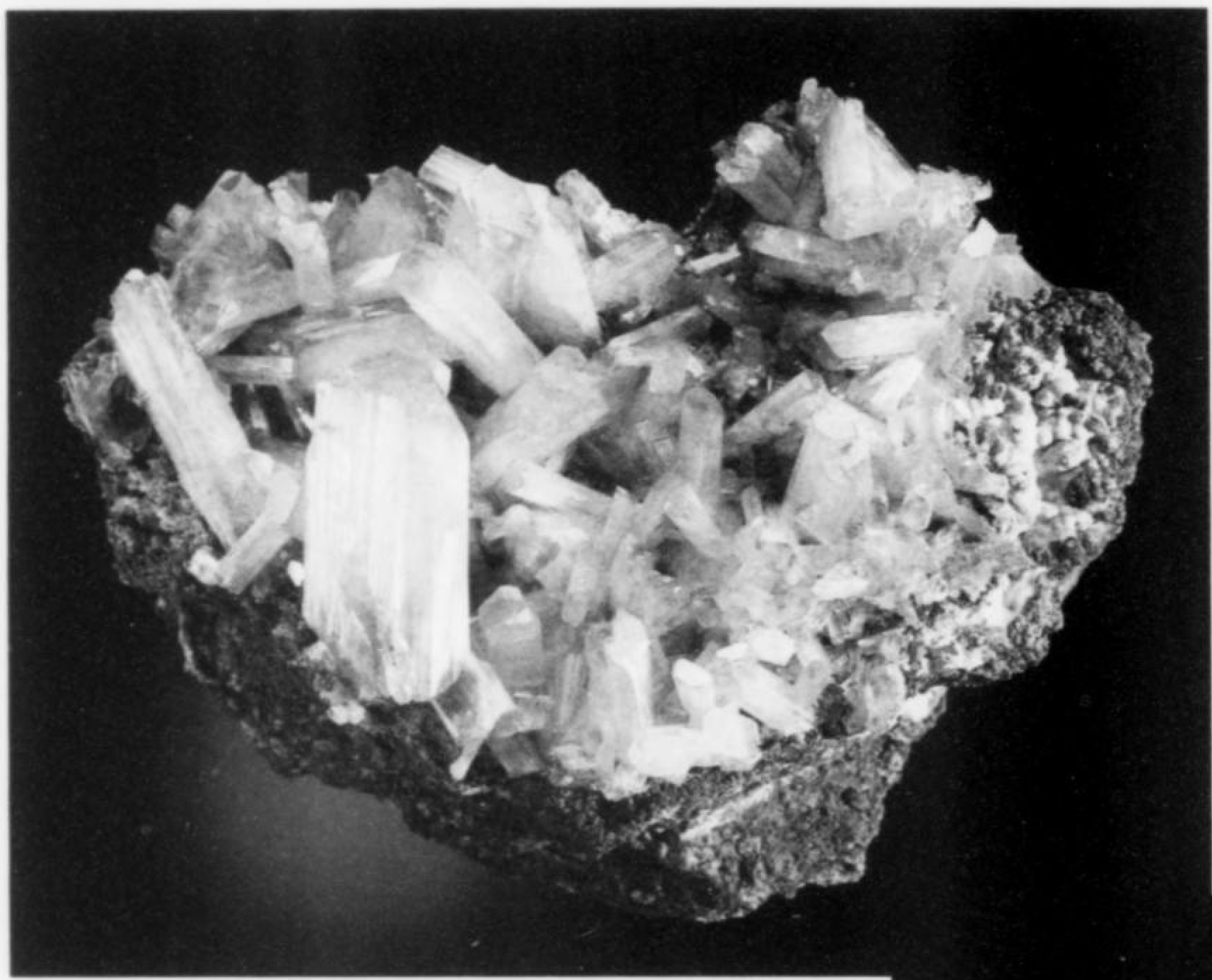


Figure 108. **Legrandite crystals on limonite, 5.6 cm, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

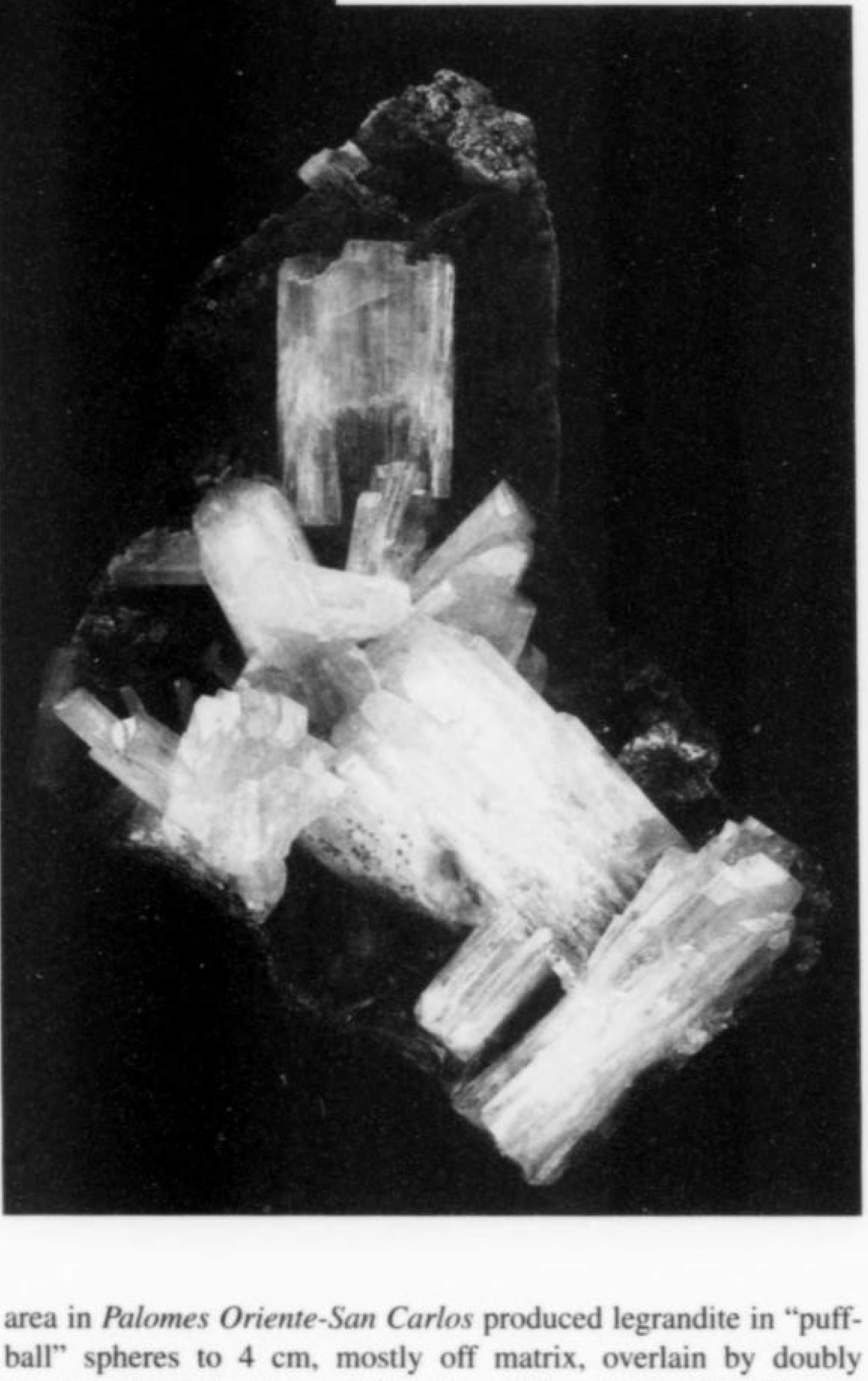


Figure 109. **Legrandite crystals on limonite, 8.4 cm, from the Ojuela mine. Wayne Thompson specimen; Jeff Scovil photo.**

Figure 110. **Legrandite crystals to 3 cm with hydrozincite (?) on limonite, from the Ojuela mine. Harvard Mineralogical Museum collection; Jeff Scovil photo.**

1968, a pocket produced more legrandite sprays to 5 cm and, thanks to the enterprise of Benny Fenn, specimens from this find caused a sensation at the 1969 Tucson Show, and a gigantic matrix piece with about seventeen 4-cm crystals went to the Smithsonian Institution (Smith and Smith, 1999a). This phase of collecting also produced excellent specimens of köttigite/parasymplesite, mapimite, ojuelaite, smithsonite and paradamite. Around 1975 a collecting area in *Palomes Oriente-San Carlos* produced legrandite in "puff-ball" spheres to 4 cm, mostly off matrix, overlain by doubly terminated paradamite crystals to 1 cm. The miners called this area *Los Changos* ("the monkeys") since, they say, you had to be agile as a monkey to work in there.

The greatest of all legrandite pockets in the Ojuela mine was found between Levels 5 and 6 in *Plan de Ayala*, in November 1977.

A Fortuitous Trade

Colonel E. M. Barron was a colorful character in the El Paso/Mexico mineral trade for many years. He died in the early 1970's, having bequeathed his personal collection and the contents of his rock shop to the University of Texas at Austin: the bequest included piles of superb Los Lamentos wulfenite, gunny sacks filled with top-grade Chihuahua agates, and a swimming pool full of geodes.

Peter Keller, a graduate student at the university, had worked as a student curator at the Smithsonian, and so was given the job of curating the "keeper" specimens in the Barron collection and managing sales of the rest, the income going to the expansion and improvement of the collection at the University. At the same time, Keller was pursuing field studies in Mexico (and pursuing his interest in mineral specimens), and so he, with several other graduate students, began to bring specimens out of Santa Eulalia and Mapimí to augment the "Barron sales."

During one of his visits to Mapimí, Keller bought a gemmy legrandite fragment from which Joe Bordan cut a 1.07-carat stone. At the time this was the world's only known faceted legrandite, and Paul Desautels wanted it very badly for the Smithsonian; Keller agreed to trade the cut legrandite (in which he had perhaps $50 invested, including the cost of the cutting) for specimens from the U.S. National Collection. Since Desautels thought that any faceted gem cut from a very rare species was worth $1000 per carat, he agreed to part with two Smithsonian specimens, each valued at $500. One of the two was an exceptional Guerrero amethyst; the other was a cabinet-sized elbaite from California. The latter specimen, unbeknownst to both Keller and Desautels, had already been selected for representation in the series of the first U.S. mineral stamps (from sketches of hundreds of specimens by postal service artists). By the time the proofs for the stamps came out, one of them showing the now famous "postage stamp tourmaline," the Keller/Desautels trade had been consummated, and the California elbaite specimen was worth enormously more than it had been before. Keller sold/traded the specimen elsewhere (eventually it passed, through David Wilber, to the John Barlow collection), further leveraging his initial $50 investment.

The final appraised value of Keller's acquisitions from this series of trades and sales was more than $200,000 in mid-1970's mineral prices.

Peter Megaw

This is the pocket from which Felix Esquivel collected the "Aztec Sun," the world's largest legrandite specimen, with scorodite microcrystals on one side—the story of the discovery is told at the end of the "History" section here. It must be noted, too, that the extensive account of the same find in Panczner (1987) incorrectly gives the date as "summer 1979.

Lepidocrocite γ-$Fe^{3+}O(OH)$

Transparent, dark reddish brown to brown lepidocrocite rosettes and single platy crystals to 1 mm have been found on ore specimens from *San Rafael*, just east of the Roebling bridge.

Elsewhere in the district the massive mineral is found in oxidized ores from many localities (Hoffmann, 1967).

Libethenite $Cu^{2+}_2(PO_4)(OH)$

Libethenite crystals to 4 mm have been found in *Santo Domingo*, associated with hemimorphite (Panczner, 1987). The crystals range from pale green to blackish green, and are short prismatic to equant and vertically striated (McGowan, 2000).

Litharge PbO

Litharge occurs exclusively in association with wulfenite in the Mapimí district, as minute inclusions which may give crystals of wulfenite a red color and turbid appearance (Hoffmann, 1967), and as sprinklings on wulfenite crystal surfaces (Panczner, 1987). Inclusions of litharge (and/or minium) are the coloring agents in red calcite from the Ojuela mine.

Lotharmeyerite $Ca(Mn^{3+},Zn)_2(AsO_4)_2(OH,H_2O)_2$

Lotharmeyerite—named after the German chemist Julius Lothar Meyer (1830–1895)—was first described by Dunn (1983) from the Ojuela mine. It was first seen as a dark reddish orange, drusy encrustation on the matrix of a specimen of the spectacular purple adamite crystals discovered in *San Judas* in 1981. On the holotype lotharmeyerite specimen in the Smithsonian, the matrix consists of

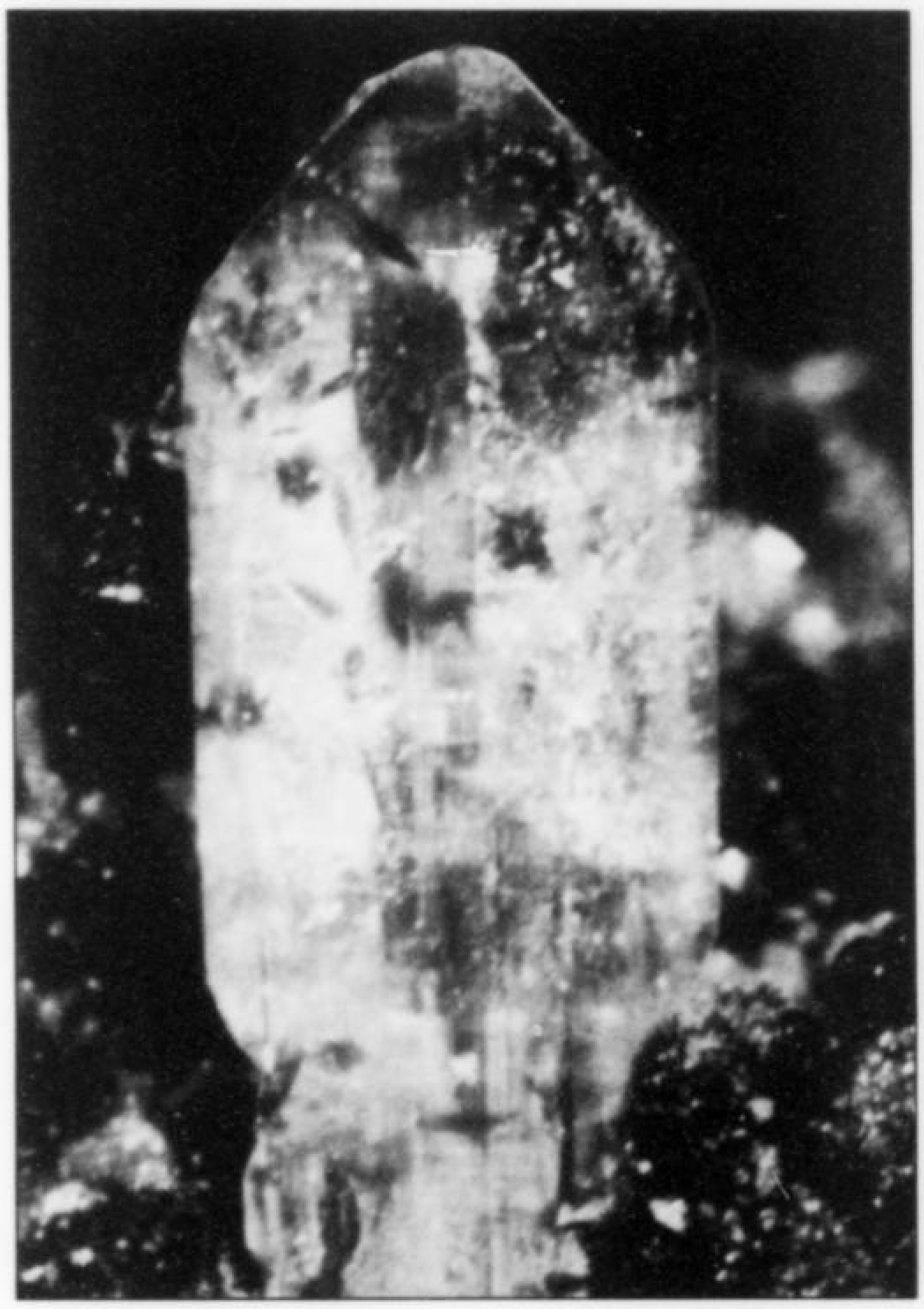


Figure 111. **Brown lotharmeyerite crystals to 1 mm on and in adamite crystal, on matrix coated by the Mn-analog of arseniosiderite, from the Ojuela mine. Los Angeles County Museum of Natural History collection; Anthony Kampf photo.**

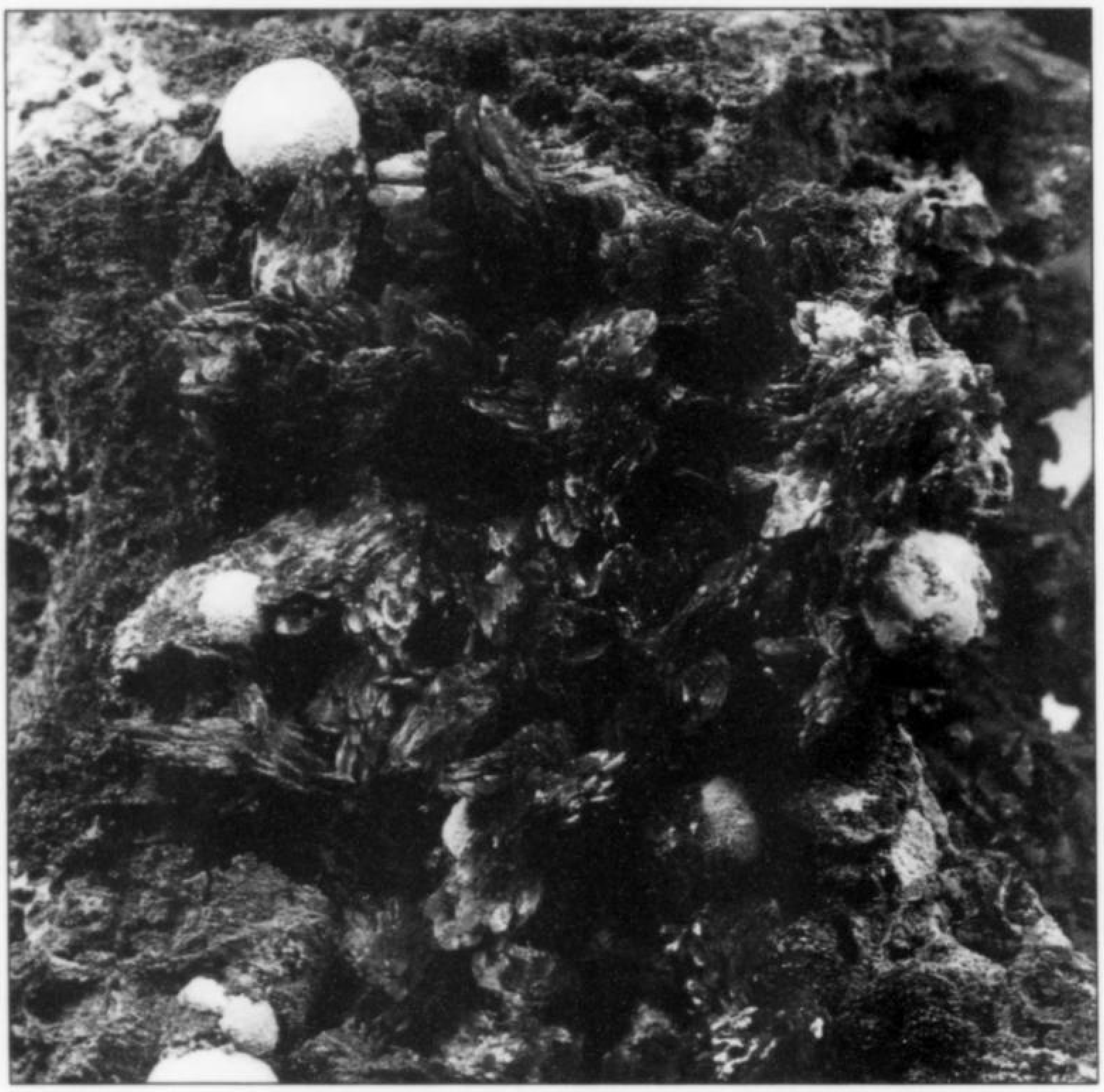


Figure 112. **Malachite spheres and crystal clusters on limonite, 6.5 cm, from the Ojuela mine, Cumbres area. Terry Stambaugh collection; Wendell Wilson photo.**

massive manganese oxides intergrown with goethite and yellow to colorless adamite; the lotharmeyerite crystals are equant and pleochroic (dark reddish orange and pale pinkish orange), but too tiny and sparse to have been completely characterized (Dunn, 1983).

A year later, working from further specimens with larger lotharmeyerite crystals from the purple adamite zone, Kampf, Shigley and Rossman were able to determine lotharmeyerite as monoclinic and to refine the formula. On these specimens the lotharmeyerite crystals (subsequently reclassified as manganlotharmeyerite; q.v.) occur as inclusions in purple adamite; they form sub-parallel aggregates of bladed crystals to about 1 mm (Kampf *et al.*, 1984).

Brugger *et al.* (2002) have recently redefined the components of the lotharmeyerite subgroup, with the result that analyses showing more Mn than Zn are now referred to the new species name manganlotharmeyerite. In the case of Ojuela mine specimens, the examples studied by Kampf *et al.* (1984) are now redefined as manganlotharmeyerite, whereas those analyzed by Dunn (1983) in the original description of the species are still classified as lotharmeyerite. An analysis of an additional Ojuela mine specimen by Brugger *et al.* (2002) confirmed the existence of lotharmeyerite there.

The best known lotharmeyerite specimen, now in the Harvard collection, is a 10 x 12-cm plate with thousands of lotharmeyerite crystals forming a crust 1.5 cm thick; purple adamite crystals rest on the crust.

Magnetite $Fe^{2+}Fe^{3+}_2O_4$

Massive magnetite has been noted at the Ojuela mine (Panczner, 1987). **Elsewhere in the district**, it is found near contact zones, partially replaced by pyrrhotite and with some alteration to hematite and goethite; it is associated also with silicates including diopside, vesuvianite, grossular and titanite. Near the intrusive body at Dinamita, magnetite and other iron oxides have been mined on a small scale at the **La Lucha mine** (Hoffmann, 1967).

Malachite $Cu^{2+}_2(CO_3)(OH)_2$

Malachite is widespread in the oxidized ores of the district, especially in the deeper portions (Hoffmann, 1967). In the Ojuela mine it is found as tiny green acicular crystals on goethite, associated with calcite and plattnerite (Johnson, 1962), and may occur as tufts included in calcite (Bancroft, 1984). Malachite tufts to 8 mm associated with azurite, cuprite, native copper and goethite have been found in *Cumbres* (Panczner, 1987); during the 1950's and 1960's, bowtie-shaped aggregates to 1 cm were collected here. In 1999, vugs lined with plush acicular malachite were found in *San Juan Poniente*, with small, beautiful azurite/calcite specimens (see under Azurite), and malachite and rosasite pseudomorphs after azurite.

Manganite $Mn^{3+}O(OH)$

Manganite is among the last manganese minerals to have formed in the manganese ores in the district, occurring in fracture fillings (Hoffmann, 1967). Euhedral crystals to 8 mm in vugs occur in the Ojuela mine (Hoffmann, 1967; Panczner, 1987).

Manganlotharmeyerite

$Ca(Mn^{3+},\square,Mg)_2\{AsO_4,[AsO_2(OH)_2]\}_2(OH,H_2O)_2$

Working with lotharmeyerite crystals from the purple adamite zone, Kampf *et al.* (1984) were able to determine lotharmeyerite as monoclinic and to refine the formula. On these specimens the lotharmeyerite crystals occur chiefly as inclusions in purple adamite; SEM photomicrographs reveal that non-included lotharmeyerite forms sub-parallel aggregates of bladed crystals to about 1 mm (Kampf *et al.*, 1984).

The Ojuela mine specimens studied by Kampf *et al.* (1984) contain more Mn than Zn; Brugger *et al.* (2002) have recently redefined the components of the lotharmeyerite subgroup, with the result that analyses showing more Mn than Zn are now referred to the new species name manganlotharmeyerite. Therefore, the Ojuela mine specimens studied by Kampf *et al.* (1984) are now redefined as manganlotharmeyerite. Although these represent the first-analyzed and reported examples of what has been defined as the new species, Ojuela is not considered the type locality because all analyses in the recent redefinition are based on specimens from the Starlera Mn mine in the Swiss Alps. Manganlotharmeyerite is brittle with an irregular fracture and distinct cleavage parallel to {001}; it is transparent to translucent, with an adamantine luster and a brown-red to dark red-orange color.

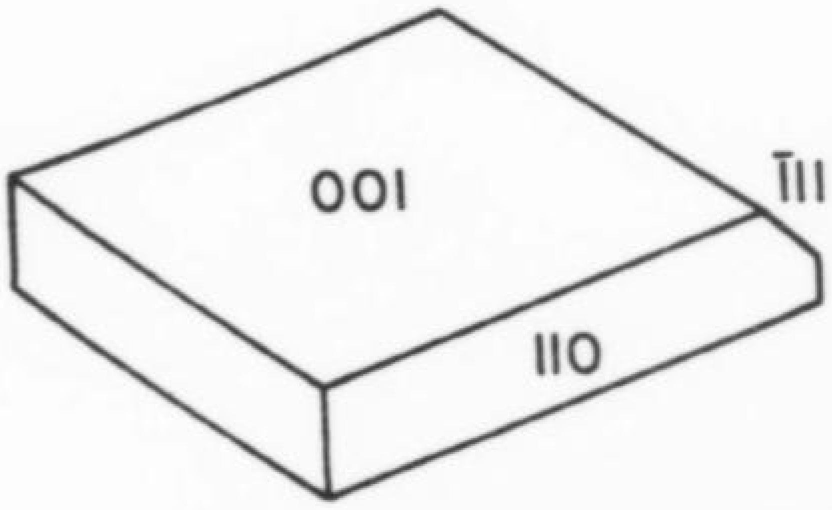


***Figure 113.* Mapimite crystal drawing, Ojuela mine (Cesbron *et al.*, 1981).**

Mapimite $Zn_2Fe^{3+}_3(AsO_4)_3(OH)_4\cdot 10H_2O$

In the legrandite zone in *Palomes Oriente*, early in the 1970's, pale green tabular crystals to 4 mm of a then-unknown species resembling torbernite (later described as mapimite) were found with needles of another unknown species (later described as ojuelaite), sparsely spotting a few pieces of gossan matrix. Nearly all of these crystals were destroyed during inconclusive testing, so the formal description of both species had to wait for a later find (Mike New, personal communication, 2002).

Mapimite and ojuelaite were formally described from the Ojuela mine by Cesbron *et al.* (1981), from specimens found in the late 1970's in *Palomas Oriente-San Carlos*. In this occurrence, mapimite formed crystals to 3 mm in vugs in goethite, associated with adamite, scorodite, ojuelaite, paradamite and smithsonite. The monoclinic, flattened mapimite crystals are strongly trichroic, blue to greenish blue to green. The habit is square platelets flattened on {001} and bounded by the prism faces {110}; a beveling face on one edge {$\bar{1}$11} is rarely present. Good cleavage is present on {001} and {010}, and the crystals are polysynthetically twinned on {001} with a [104] pseudoaxis. The Ojuela mine is currently the only known locality for the species.

Marcasite FeS_2

Marcasite is common in the primary ores of the district, frequently replacing pyrrhotite and enargite. In the Ojuela mine, intergrowths of pyrite and marcasite replace pyrrhotite in the sulfide ores of *Monterrey* (Hoffmann, 1967).

"Mazapilite"

"Mazapilite" was described as a species in 1889, and at first this name was applied to some sharp brown crystals found in 1927 by Foshag near the town of Ojuela, in an assemblage with carminite, scorodite, dussertite and arseniosiderite. But Foshag (1937) found the crystals to be arseniosiderite pseudomorphs after scorodite, and the species "mazapilite" is now discredited (Bayliss, 2000).

Melanterite $Fe^{2+}SO_4\cdot 7H_2O$

Pale green to bluish green melanterite occurs with chalcanthite along fault-gouge and fracture zones, frequently mixed with goethite (Hoffmann, 1967).

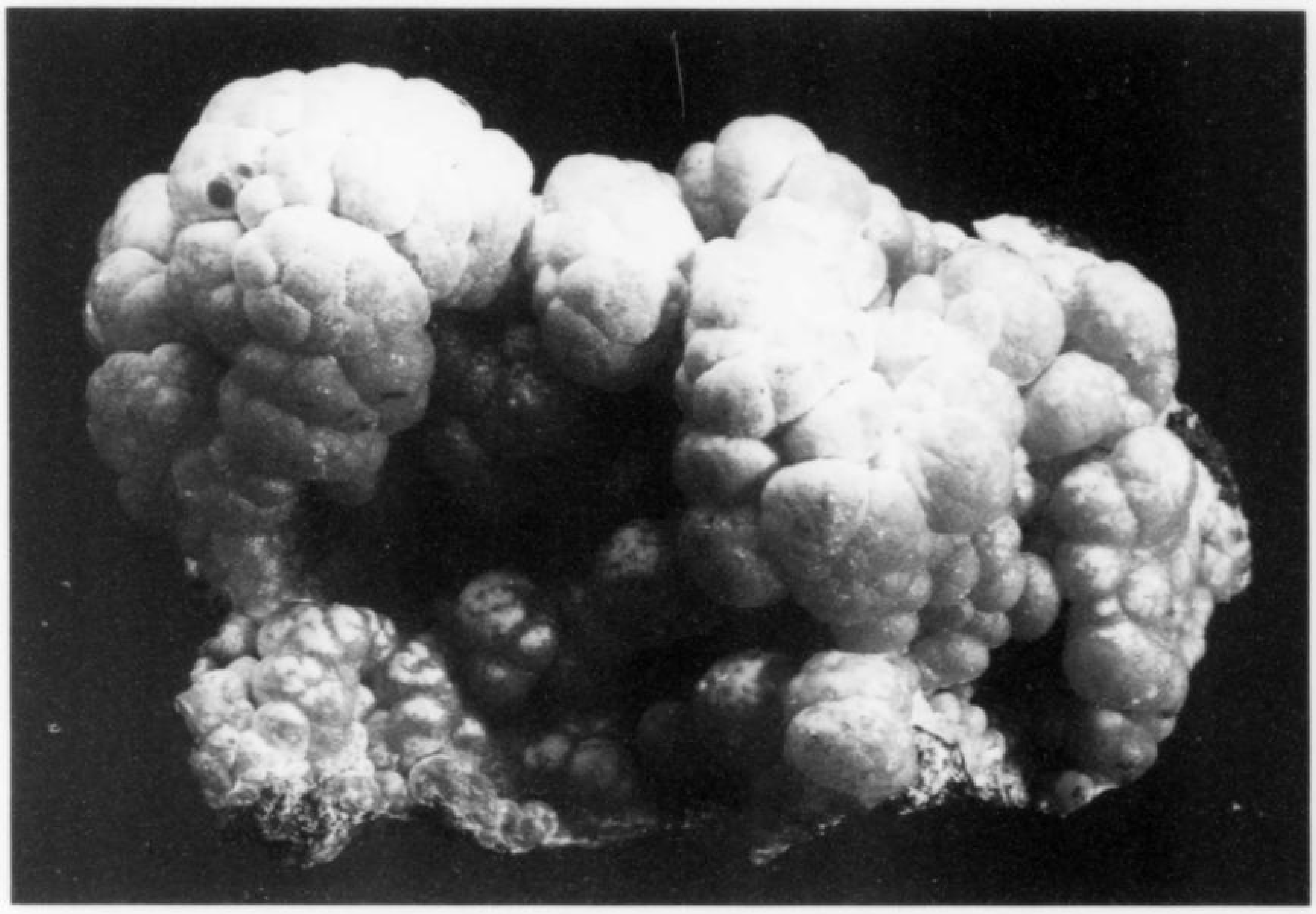


***Figure 114.* Botryoidal mimetite, 3.3 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.**

Metaköttigite $(Zn,Fe^{3+},Fe^{2+})_3(AsO_4)_2\cdot 8(H_2O,OH)$

Described in 1982 by Schmetzer *et al.*, metaköttigite is the Zn analog of symplesite and the triclinic dimorph of köttigite. It occurs with köttigite, adamite and smithsonite on goethite in the lower part of the oxidation zone in the Ojuela mine, in minute, bluish gray, tabular crystals in oriented intergrowth with köttigite. Schmetzer *et al.* (1982) consider that oxidation of Fe^{2+} to Fe^{3+} and simultaneous conversion of H_2O to OH^- result in the transition from monoclinic köttigite to triclinic metaköttigite.

Mimetite-Pyromorphite $Pb_5(AsO_4,PO_4)_3Cl$

A complete series between mimetite and pyromorphite exists in the oxidized lead ores of the Mapimí district (Johnson, 1962), with specimens in the mimetite range being much the more common. Hoffmann (1967) analyzed small, colorless, transparent crystals and

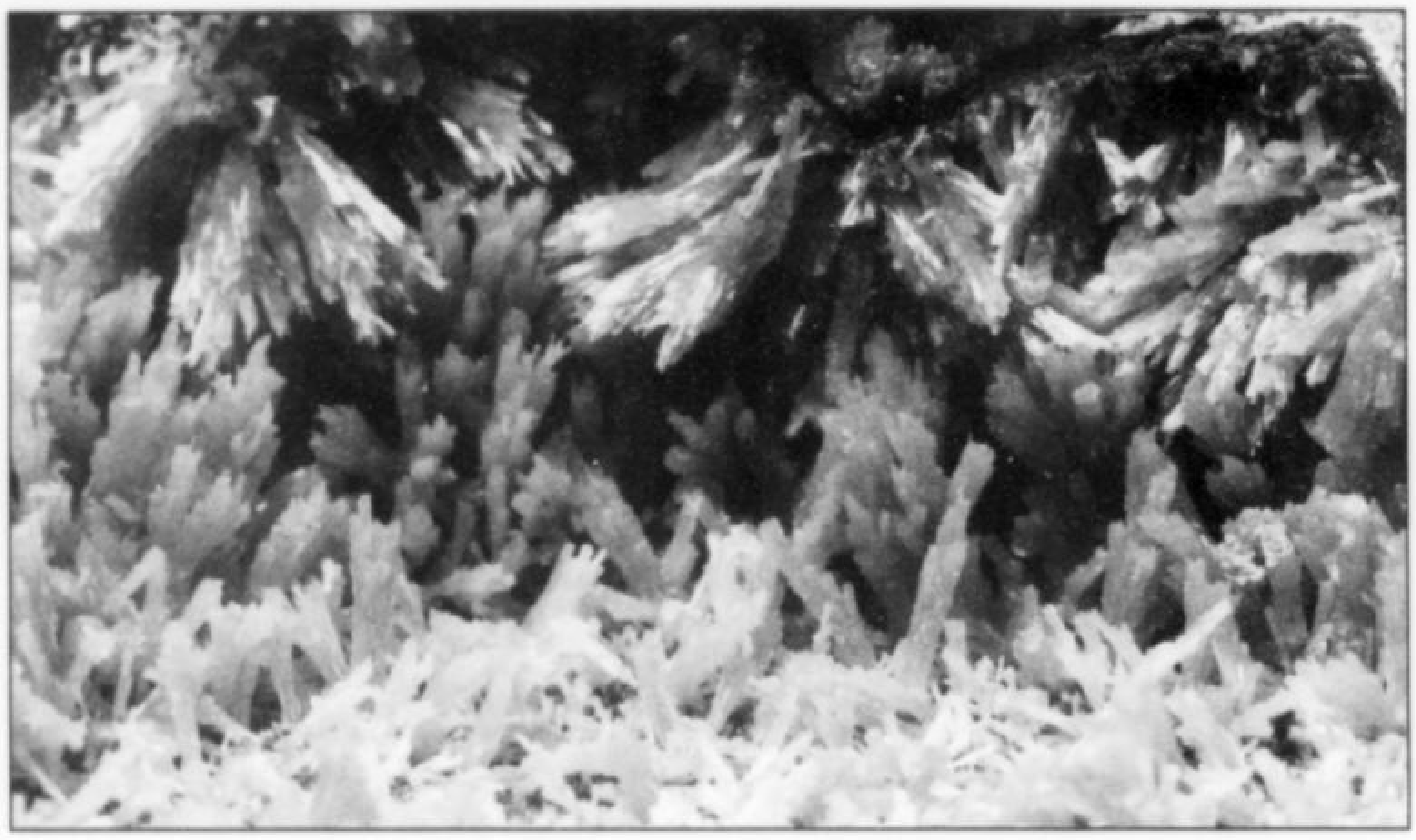


Figure 115. **Pyromorphite crystals to 5 mm from the Ojuela mine. Terry Stambaugh collection; Wendell Wilson photo.**

found them to contain less than 0.1 percent P_2O_5, while in other samples analyzed the maximum P:As ratio was 7:10. However, the Ojuela mine has produced pale yellow to green pyromorphite crystals to 8 mm, and mimetite crystals of the same colors to 6 mm (Panczner, 1987). Mimetite-pyromorphite is seen as globular to stalactitic crystals on goethite matrix, associated with calcite and wulfenite (Johnson, 1962), and as pale yellow-green crystals and masses associated with goethite, cerussite, anglesite, plumbojarosite, bindheimite and wulfenite (Hoffmann, 1967; Panczner, 1987). Stam-baugh (2002) shows on his website a specimen of golden prismatic mimetite crystals to 5 mm scattered on black manganese oxide matrix.

In 1968, on Level 5 of *Campana*, miners of the co-operative collected and sold (to Parser's Minerals) about a ton of specimens of attractive green botryoidal mimetite emplanted with wulfenite crystals, and in 1981 the same area produced about 200 good specimens of the same type. As of this writing (2003), *Campana* is once again giving up specimens of mimetite in silky green botryoids in highly vuggy goethite, with white calcite and wulfenite crystals—these specimens are coming from Level 7.

In 1981, in the adamite zone on Level 4, about 15 specimens were found representing the mine's best known mimetite, and an exception to the rule that the species occurs only in small barrel-shaped crystals or globular forms. In these specimens, lustrous, translucent yellow mimetite prisms with pyramidal terminations to 3 cm long, and about as thick as a pencil lead, are emplanted on goethite (Mike New, personal communication, 2002).

Elsewhere in the district, microcrystals of mimetite have been found in numerous small mines and prospects (Peter Megaw, personal communication, 2003); Panczner (1987) notes the **San Juan mine** as one of these.

Minium $Pb_2^{2+}Pb^{4+}O_4$

Very finely divided red-orange minium has been observed on (and in?) bright orange wulfenite crystals and in small vugs in goethite in the Ojuela mine, associated with adamite, mimetite, wulfenite and bindheimite (Hoffmann, 1967).

Mn-analog of Arseniosiderite $Ca_2Mn_3^{3+}(AsO_4)_3O_2\cdot 3H_2O$

The Mn-analog of arseniosiderite was first reported from the Ojuela mine (but not described or named) by Kampf *et al.* (1984), who identified it as a druse of microcrystals associated with adamite and lotharmeyerite (now = manganlotharmeyerite). The crystals are very small (0.01 mm), thin, pale brown platelets or blades with sharp edges and rounded outlines, in tight druses of crystals oriented with the axis normal to the plane of flattening lying parallel to the matrix surface, that is, with the blade edges all pointing upward. Semiquantitative EDS analyses performed by Kampf (personal communication, 2003) on the specimen he described in 1984 have indicated that the mineral may contain around 20–25% Mn and less than 1% Fe; although these numbers are only approximate, they conclusively prove that Mn is dominant over Fe in this material. However, it has not yet been formally described and named as a new species.

Molybdenite MoS_2

Although the ores of the district contain no large masses of molybdenite, it is widely distributed in small amounts in the unaltered sulfide zones (Hoffmann, 1967). Distorted tabular crystals and rosettes to 4 mm occur in the Ojuela mine with sphalerite, pyrite and galena (Hoffmann, 1967; Panczner, 1987), and molybdenite rosettes enclosed in cryptomelane and pyrolusite were noted in a manganese ore pile at the south end of the Roebling suspension bridge at Ojuela (Hoffmann, 1967).

Murdochite $PbCu_6^{2+}O_{8-x}(Co,Br)_{2x}$

Lustrous black, simple octahedral crystals of murdochite, seldom more than 1 mm, occur with plattnerite, hemimorphite and calcite on goethite matrix (Johnson, 1962; Hoffmann, 1967). Panczner (1987) records murdochite crystals to 3 mm from the Ojuela mine.

Nantokite CuCl

Nantokite occurs in intergrowths with rosasite, aurichalcite, plattnerite, malachite and cerussite on the surfaces of cerussite pseudomorphs after hemimorphite (?) in Ojuela mine specimens in the Smithsonian Institution (John White, personal communication, cited in Hoffmann, 1967).

Ogdensburgite $Ca_2(Zn,Mn^{2+})Fe_4^{3+}(AsO_4)_4(OH)_6\cdot 6H_2O$

Ogdensburgite was described as a new species in 1981 and named after its type locality, the Sterling Hill mine at Ogdensburg, New Jersey; there it was found in 0.1-mm encrustations of brownish red, platy crystals. But also in 1981, bladed ogdensburgite crystals to 1 mm were found on a single specimen from between the 6th and 7th levels of the Ojuela mine—in the *San Judas* chimney, then being worked by John Whitmire and Mike New for the famed purple adamite crystals (Kampf and Dunn, 1987; Panczner, 1987). The ogdensburgite occurs on goethite within an aureole of massive chalcophanite; the association also includes colorless to pale green (not purple) adamite, arseniosiderite and 4-cm pink crystals of villyaellenite (Kampf and Dunn, 1987). Panczner (1987) notes that there were "a few" specimens containing ogdensburgite in the area of this find, and that the ogdensburgite

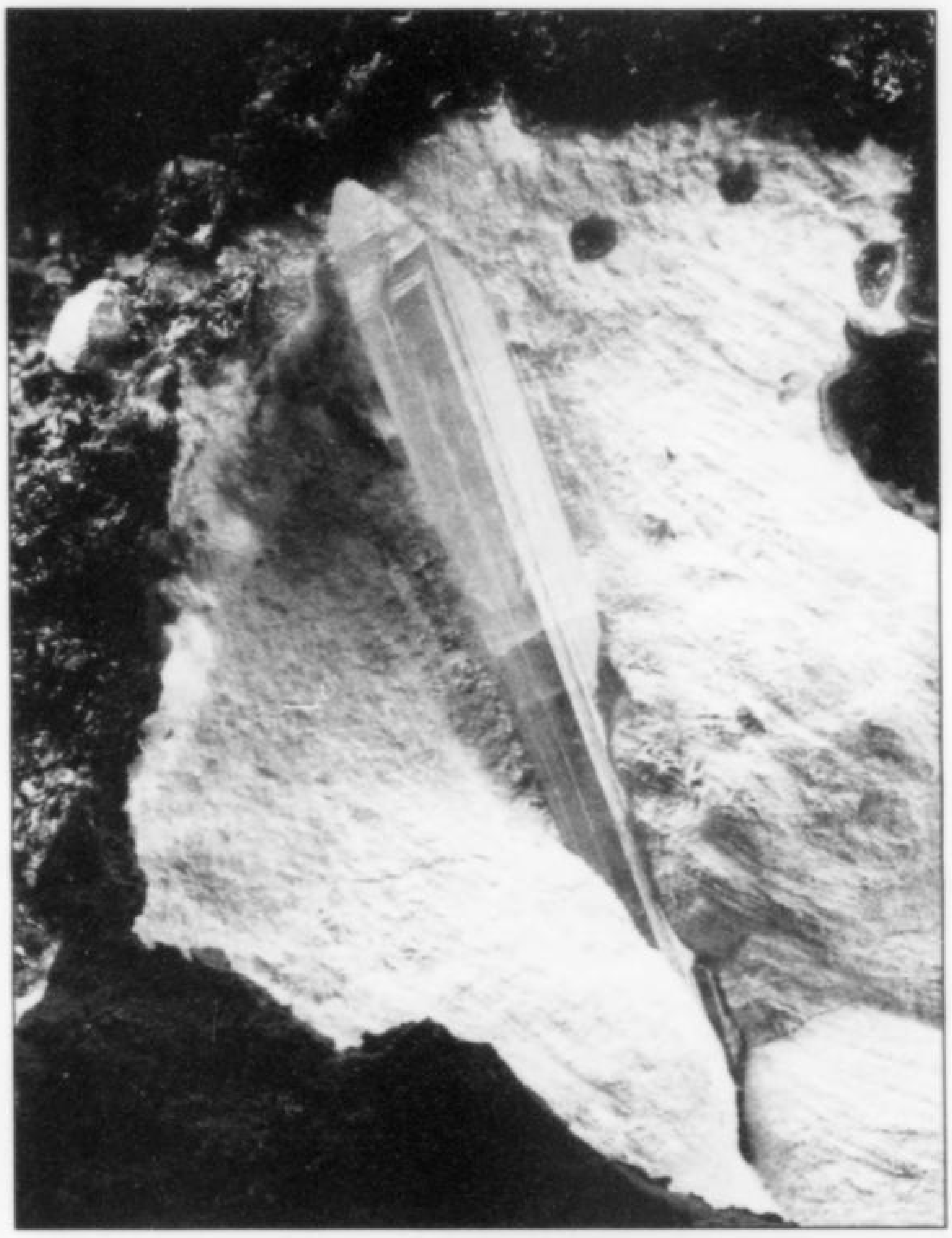


Figure 116. **Legrandite crystal (1.3 cm) on a felted coating of ojuelaite, from the Ojuela mine. William Severance collection; Jeff Scovil photo.**

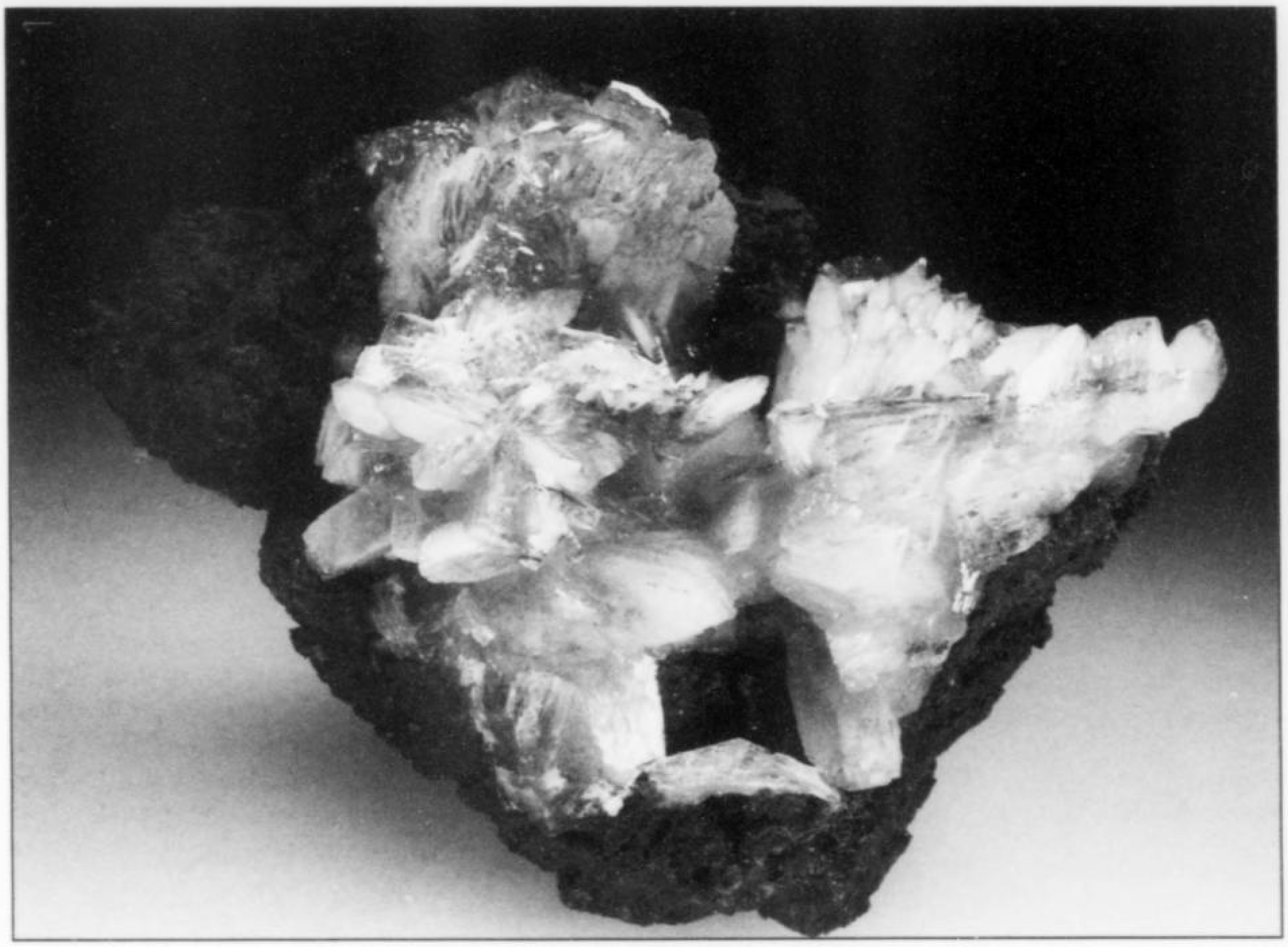


Figure 117. **Paradamite crystal clusters on limonite, 8 cm, from the Ojuela mine. Finest known specimen of the species. Miguel Romero collection, now at the University of Arizona Mineral Museum; Wendell Wilson photo.**

crystals reach 2 mm. They are orthorhombic, bladed, and dark brownish red, exhibiting a perfect cleavage along {001} (Kampf and Dunn, 1987).

Ojuelaite $ZnFe_2^{3+}(AsO_4)_2(OH)_2 \cdot 4H_2O$

A find in the early 1970's in the legrandite zone in *Palomes Oriente* produced a small number of acicular yellow crystals of a then-unknown species that would later be named ojuelaite. The discovery yielded a few crystals to 2.5 cm lying flat on gossan matrix (Mike New, personal communication, 2002). As with the other unknown species recovered in that find (later named mapimite), those specimens were mostly lost and/or destroyed during inconclusive testing.

Ojuelaite (with mapimite) was first described formally from the Ojuela mine in 1981 by Cesbron *et al.*; the type specimens also came from *Palomas Oriente*. The species occurs as flexible, chartreuse-colored, silky to vitreous monoclinic fibers to 4 mm, elongated parallel to [001], in some cases as felted masses lining legrandite pockets. The crystals usually occur in divergent sprays on goethite, associated with scorodite, smithsonite, paradamite and mapimite (Cesbron *et al.*, 1981; Panczner, 1987); a good cleavage exists on {010}. Although the Ojuela mine remains the only known occurrence of mapimite, ojuelaite has since been found at Tsumeb, Namibia; Pitiquito, Sonora, Mexico; and the Sterling Hill mine, Ogdensburg, New Jersey.

Paradamite $Zn_2(AsO_4)(OH)$

Paradamite was described from the Ojuela mine in 1956, from a suite of secondary minerals in which the paradamite was associated with adamite, mimetite and legrandite in goethite vugs (Switzer, 1956). The original specimens were collected by George Griffith of Gomez Palacio, then sold to George Burnham of California before finding their way to the Smithsonian to be characterized as a new species (Switzer, 1956). Paradamite is the triclinic dimorph of orthorhombic adamite; according to Johnson (1962), it can form as a paramorphic pseudomorph after adamite as well. It is found as lustrous pale to medium-yellow, sheaflike crystal aggregates and equant, striated individual crystals with adamite and mimetite on goethite (Johnson, 1962). Although a few spectacular specimens have been found, paradamite remains an extremely rare mineral in the Ojuela mine, particularly in contrast to the abundant adamite which it so closely resembles. Panczner (1987) mentions paradamite crystals to 3 cm from the Ojuela mine, and White (1971) reports an "exciting new find" of paradamite appearing on the market in the early 1970's, with about 30 specimens showing up at the Tucson Show. The best Ojuela paradamite specimen is certainly the one in the Miguel Romero collection at the University of Arizona: a 6.7-cm goethite matrix almost entirely covered with large, sharp, lustrous, intergrown paradamite crystals of a rich yellow color (Wallace, 1999). Curt Van Scriver bought this piece from Salvador Davila for one dollar—both buyer and seller thought it was adamite.

As in the case of legrandite, Mexican specimens of paradamite went completely unrivaled in the world until the early 1990's, when the so-called "Zinc Pocket" in the lowest levels of the Tsumeb mine produced four exceptional paradamite specimens (translucent, cream-colored, 1-cm crystals in clusters on matrix to 8 cm), just before the mine's final closure (Gebhard, 1999).

The miners recall two especially exciting discoveries of paradamite, both in association with legrandite. From the late 1960's through the mid-1970's, legrandite pockets in *Palomes Oriente-San Carlos* produced the 3-cm paradamite crystals mentioned above; the specimen in the Romero/University of Arizona collection is from this zone. Later, in the *Los Changos* collecting area in the same zone, doubly terminated paradamite crystals to 1 cm were found perched on surfaces of loose "puffball" spheres of legrandite.

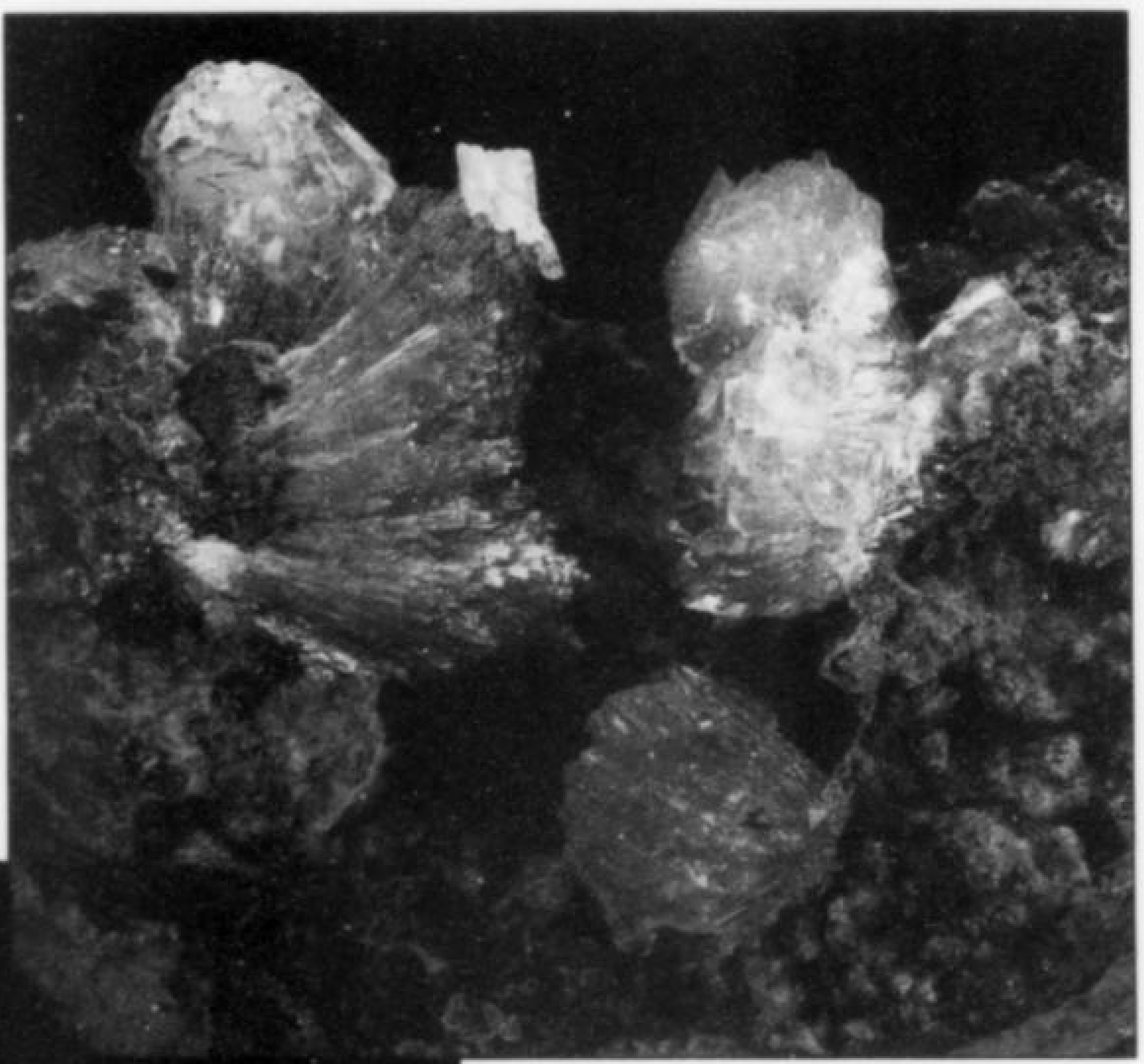


Figure 118. **Paradamite crystal clusters on limonite, 3.5 cm, from the Ojuela mine. Martin Zinn collection; Jeff Scovil photo.**

Figure 119. **Paradamite crystal cluster on limonite, 4.5 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.**

Parasymplesite See **Köttigite-Parasymplesite**

Pharmacosiderite $KFe_4^{3+}(AsO_4)_3(OH)_4 \cdot 6\text{–}7H_2O$

Tiny cubic crystals of pharmacosiderite in various shades of green, yellow, brown and red have been noted from the Ojuela mine (McGowan, 2000). During the 1970's, a few specimens with sharp pharmacosiderite crystals to 4 mm, associated with legrandite, were found in *San Juan Poniente*; the crystals are cubes with octahedral truncations on four corners only, precisely as shown in Dana (1949) for Cornwall pharmacosiderite. Mike New (personal communication, 2003) recalls handling some specimens from *Palomas Oriente* with pharmacosiderite crystals to 6 mm. Specimens are also known in which pharmacosiderite cubes to 1 mm rest on adamite crystals (Marcus Origlieri, personal communication, 2003).

Plattnerite PbO_2

Plattnerite occurs in sharp, brilliant black acicular crystals to 5 mm in the Ojuela mine, in goethite cavities associated with hemimorphite, smithsonite, calcite, rosasite, hydrozincite, aurichalcite, malachite and murdochite (Hoffmann, 1967; Panczner, 1987). White (1970b) found the crystals to be tetragonal prisms elongated along [001], with no more than five forms: first and second-order prisms, tetragonal and ditetragonal dipyramids, and pinacoids. He also found that some of the tiny crystals are contact or penetration twins on {011} resembling rutile twins (White, 1970b).

From time to time in the 1950's and 1960's, fairly attractive specimens of Ojuela mine plattnerite appeared on the market, with generous blankets of microcrystals over the rough goethite matrix, nicely color-contrasted with the associated copper and zinc species. Scott Williams (1956) wrote:

> A fabulous occurrence of the comparatively rare lead dioxide plattnerite has been found in a small amounts at the famous old mining district, the Ojuela mine . . . These very brilliant,

> jet-black tetragonal, needle-like crystals . . . are available in many different combinations: scattered on hemimorphite; solid velvety coatings on matrix; groups of crystals on, and included in, calcite crystals (with or without hemimorphite); and in unusual stalactitic growths, effecting spectacular specimens . . . The crystals are small (1 to 2 mm), but are so profuse in number that the mineral is clearly visible on each specimen . . . A very few have geniculated and penetration twin crystals . . . These may be easily seen with any magnifier.

These specimens probably came from *America Poniente*, where large quantities of plattnerite were collected during the 1960's, and where, the miners say, more such material remains, uncollected, today.

Plumbojarosite $PbFe_6^{3+}(SO_4)_4(OH)_{12}$
Pulverulent yellow-brown masses of plumbojarosite, altered from lead and iron sulfides, are fairly common in the oxidized ores of the Mapimí district (Hoffmann, 1967). Panczner (1987) notes an occurrence of plumbojarosite masses from the *San Diego* stope on Level 6 of the Ojuela mine, with bindheimite, mimetite and wulfenite.

"Psilomelane"
"Psilomelane," now discredited as a species name (Bayliss, 2000), is used by Hoffmann (1967) to refer to botryoidal crusts and masses of a black manganese oxide which alters from pyrolusite and cryptomelane. In polished sections, the botryoidal formations are seen to be composed of acicular crystals in radiating clusters (Hoffmann, 1967).

Pyrargyrite Ag_3SbS_3
Massive, disseminated pyrargyrite has been noted in the upper lead/silver ore zones in the Mapimí district, associated with galena, pyrite, chalcopyrite and sphalerite; it also occurs in carbonate veins, with calcite, siderite, ankerite, barite and fluorite (Hoffmann, 1967).

Pyrite FeS_2
Pyrite is widely distributed in the unoxidized ores of Mapimí, associated with other sulfides (Hoffmann, 1967). Pyrite crystals to 4 cm have been found in the district (Panczner, 1987), but probably not in the Ojuela mine; on these crystals the pyritohedral form predominates, although the cube, octahedron and diploid have also been seen (Hoffmann, 1967).

Pyrolusite $Mn^{4+}O_2$
Pyrolusite occurs in the upper oxidized zone in the Ojuela mine, associated with hausmannite, manganite and goethite (Hoffmann, 1967; Panczner, 1987). Lustrous black, botryoidal pyrolusite crusts have been collected fairly frequently in the mine.

Pyrrhotite $Fe_{1-x}S$
Pyrrhotite is one of the earliest minerals to have formed in the massive sulfide ores in many mines of the district; it may be partially replaced by later sulfides. In general, the more pyrrhotite in the ore, the lower the arsenic content of the ore: apparently pyrrhotite forms in place of arsenopyrite in arsenic-deficient environments (Hoffmann, 1967). At *Monterrey* in the Ojuela mine, massive pyrrhotite is associated with sulfides and with euhedral 3-cm diopside crystals (Hoffmann, 1967).

Quartz SiO_2
A few small groups of colorless to white quartz crystals, commonly coated by iron oxides and slightly corroded, have been found in the upper portions of the mines in the district, and drusy quartz sometimes forms thin coatings on secondary copper and zinc minerals (Hoffmann, 1967). Amethystine quartz crystals seldom exceeding 1 cm occur in several of the shallow mines north of the Ojuela mine (Hoffmann, 1967).

Ramsdellite $Mn^{4+}O_2$
Small, irregular grains of ramsdellite in pyrolusite have been observed in polished sections of the manganese ores (Hoffmann, 1967).

Realgar AsS
Massive encrustations of red to orange-yellow realgar have occasionally been seen in the Ojuela mine (McGowan, 2000).

Rosasite $(Cu^{2+},Zn)_2(CO_3)(OH)_2$
Rosasite occurs as velvety spherules and botryoidal crusts on goethite and other oxidized copper or zinc minerals; some of the

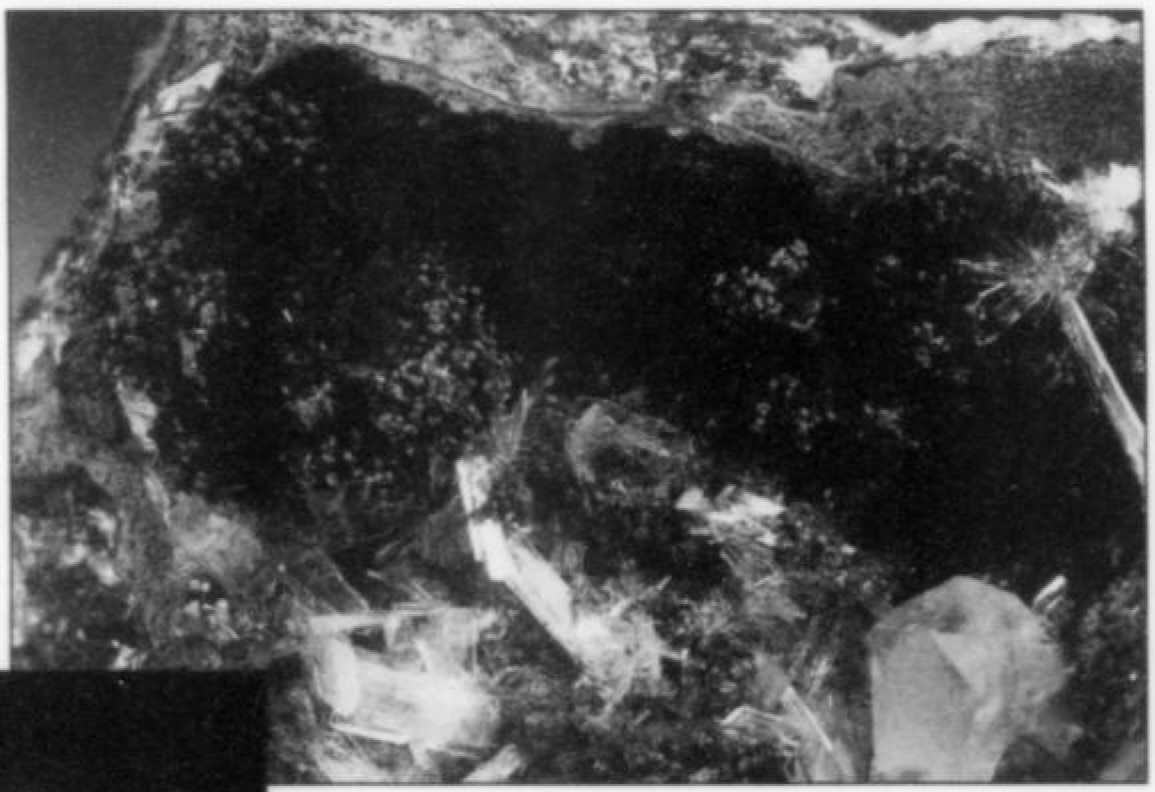


***Figure 120.* Rosasite on limonite with hemimorphite, 4 cm, from the Ojuela mine. Charles Thompson collection; Wendell Wilson photo.**

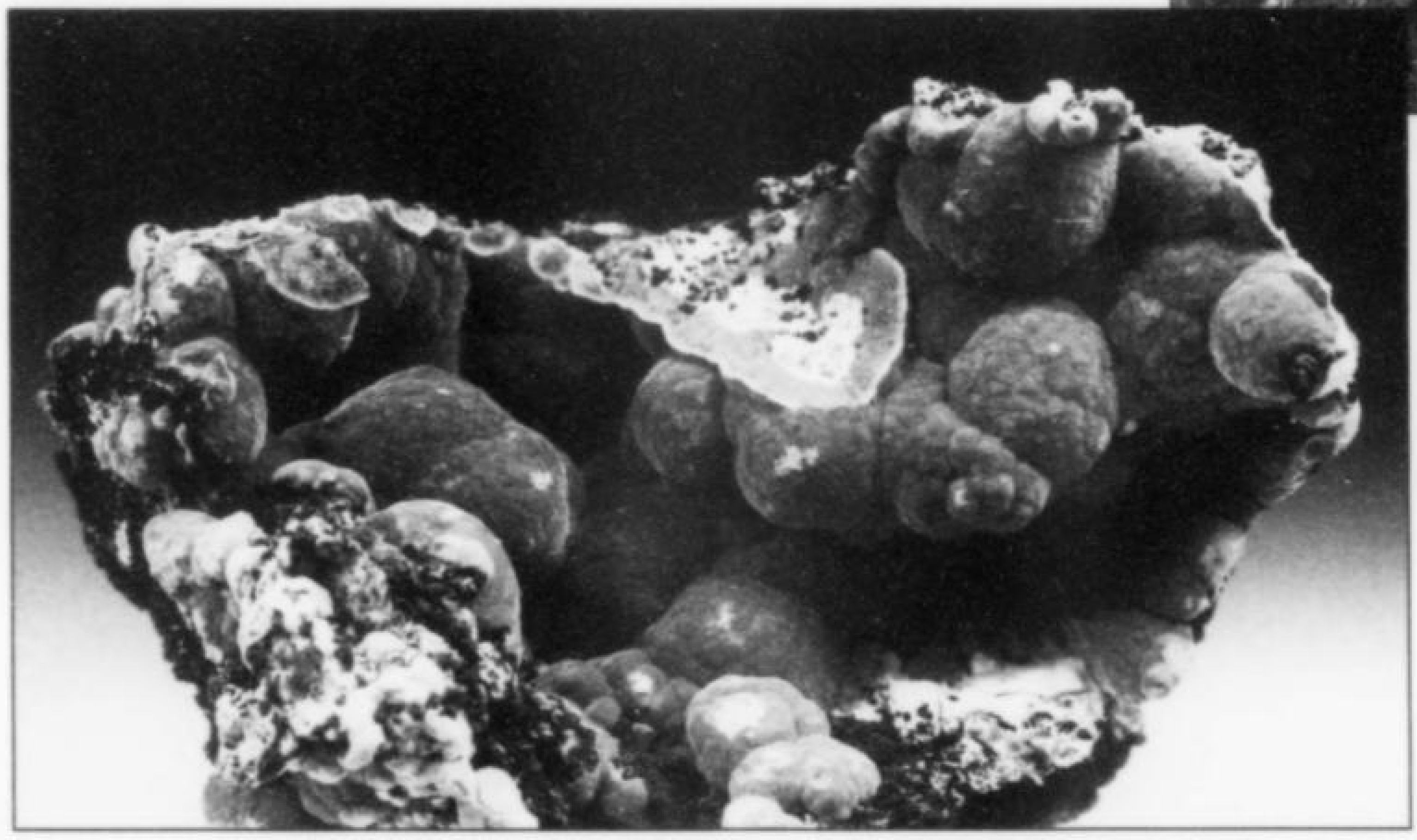


***Figure 121.* Botryoidal rosasite, 3.1 cm, from the Ojuela mine. Thomas Moore collection; Wendell Wilson photo.**

crusts have cores of malachite, and grade outward in color, from green malachite in the center to greenish blue rosasite at the outer surface, probably representing a solid solution series as malachite is enriched by zinc (Hoffmann, 1967). Rosasite is among the uncommon species found in appealing specimens in the Ojuela mine, particularly in *San Juan Poniente* (Panczner, 1987). In some cases the bright blue spherules are encrusted by colorless, bright hemimorphite crystals associated with aurichalcite (Johnson, 1962), and in other specimens the densely packed rosasite spherules with projecting microcrystals make for a beautiful velvety coating on the brown goethite matrix (Jones, 1971a). Rosasite is much rarer in Mapimí than aurichalcite, and is distinguished from it by a deeper blue color and by the spherulitic habit, as opposed to the sprays of acicular crystals formed by aurichalcite (Jones, 1971a).

The Ojuela mine's best rosasite occurs as spheres to 2 cm on white to cream-colored to transparent calcite on Level 4 of *Cumbres* and Level 3 above *America Poniente*; the latter *lugar* has yielded rosasite specimens for decades, and the material is still collectible there.

Sauconite $Na_{0.3}Zn_3(Si,Al)_4O_{10}(OH)_2 \cdot 4H_2O$

Sauconite has been found in pale gray, pulverulent coatings with hemimorphite and various manganese oxides on specimens from near the *Socavon Shaft* (Hoffmann, 1967).

Schulenbergite $(Cu^{2+},Zn)_7(SO_4,CO_3)_2(OH)_{10} \cdot 3H_2O$

Specimens of schulenbergite have frequently been misattributed to the Ojuela mine, but the species has not been found at Ojuela (Peter Megaw, personal communication, 2003). Like serpierite (see below), fine microcrystal specimens of schulenbergite have been collected for about 25 years from the **Platosa mine**, north of Bermejillo, and are still being collected; the schulenbergite crystals are associated with gypsum, smithsonite and serpierite.

Scorodite $Fe^{3+}AsO_4 \cdot 2H_2O$

Scorodite was noted in the arseniosiderite-dussertite-carminite-scorodite assemblage collected in 1927 near the town of Ojuela (Foshag, 1937). The gray-green scorodite crystals are simple in habit, consisting of the pyramid {111} only slightly modified by two other forms, so that the habit is generally pseudo-octahedral (Foshag, 1937). At the same occurrence scorodite also was noted as coarse granular masses and rounded concretionary masses abundantly veined by brown arseniosiderite, with pockets of carminite and dussertite (Foshag, 1937).

In 1981, in the workings for purple adamite and rare arsenates in *San Judas*, Mike New collected excellent clusters of blue scorodite crystals, with individuals to 2 cm, in small vugs in a compact goethite; the best of these specimens are now in the Harvard Collection (Panczner, 1983b; Mike New, personal communication, 2002).

Scrutinyite α-PbO_2

Orthorhombic PbO_2 was synthesized in 1946 and its structure characterized in 1950; known as α-PbO_2 as distinct from tetragonal α-PbO_2, it is considered a fundamental structure type among the MO_2-type oxides (see Taggart *et al.*, 1988). The natural compound, scrutinyite, was characterized from an occurrence in the Hansonburg mining district, Socorro County, New Mexico, but was noted at about the same time on material collected by Ramon DeMark in 1977 in the Ojuela mine. Scrutinyite occurs as dark reddish brown, bladed, submetallic crystals which are translucent red on thin edges, their general appearance recalling (much larger) crystals of hübnerite; at both localities the scrutinyite blades are only about 25μ across and 2μ thick, and are associated with plattnerite. In the Ojuela material, the minute flakes of scrutinyite are clove-brown and less transparent, and are mostly found within plattnerite and

Figure 122. **Scorodite crystals to 3 mm coating limonite, from the Ojuela mine, San Judas chimney. Kerith Graeber collection; Jeff Scovil photo.**

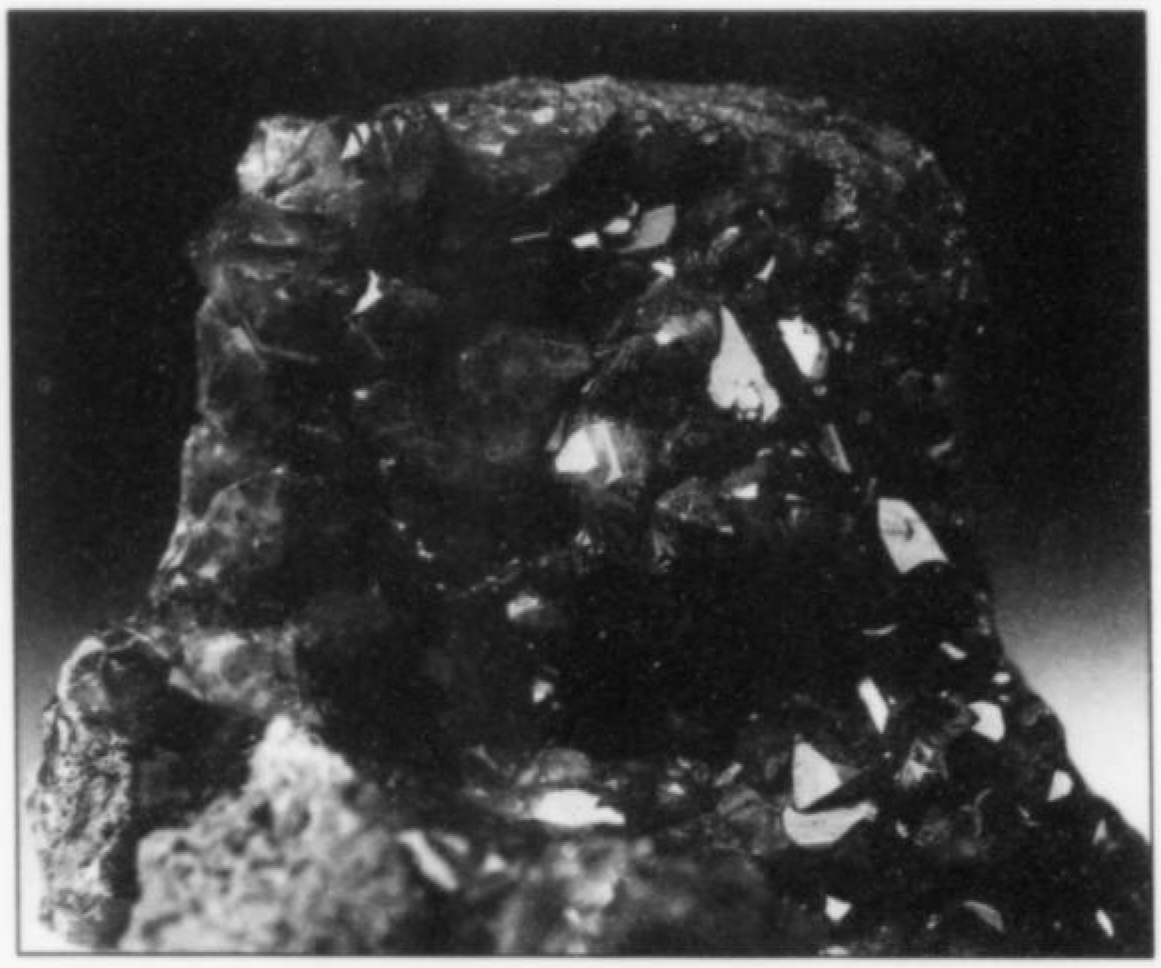


Figure 123. **Scorodite crystals on limonite, 2.5 cm, from the Ojuela mine, San Judas chimney. Terry Stambaugh collection; Wendell Wilson photo.**

Figure 124. **Colorless smithsonite crystals on matrix, 6 cm, from the Ojuela mine, Palomas Oriente *lugar*. Kerith Graeber collection; Jeff Scovil photo.**

probable plattnerite paramorphs after scrutinyite, on a typical gossany goethite matrix with rosasite. The name of the new species is, to quote from its authors, "from the word scrutiny: a close, careful examination or study; a critical sustained look, [alluding to] the close scrutiny required to recognize the unique properties of the material, and the sustained examination required to determine the physical properties with a very limited amount of sample material" (Taggart *et al*., 1988).

Segnitite $PbFe_3^{3+}H(AsO_4)_2(OH)_6$

Segnitite, with beudantite, has been noted in tiny yellow porous masses hosting 0.1-mm rosettes of crystals of the newly described species sewardite (the Ca analog of carminite) (Kolitsch, 2002).

Serpierite $Ca(Cu^{2+},Zn)_4(SO_4)_2(OH)_6\cdot 3H_2O$

Although excellent specimens of serpierite are sometimes wrongly attributed to the Ojuela mine, the species has not been found there. Serpierite, as 2.8-cm spheres of radiating acicular crystals and as 1.5-cm platy single crystals, has been found since the late 1970's at the **Platosa mine**, north of Bermejillo (Mike New, personal communication, 2002; Peter Megaw, personal communication, 2003).

Sewardite $CaFe_2^{3+}(AsO_4)_2(OH)_2$

Sewardite, the Ca-dominant analog of carminite, has very recently been characterized as a mineral species from its type occurrence at Tsumeb, Namibia; here, sewardite is found as dark red to orange, 0.3-mm subhedral to anhedral masses with green to black botryoidal masses of two intergrown tsumcorite-group minerals (Roberts *et. al*., 2002). The occurrence of the new species at the Ojuela mine was verified, later in 2002, by quantitative electron-microprobe analysis and Gandolfi X-ray testing.

Ojuela mine sewardite is found as lustrous, deep red rosettes of subparallel tabular crystals, the rosettes reaching 0.1 mm in diameter, in yellowish, porous masses of a fine-grained intergrowth of beudantite and segnitite (Kolitsch, 2002). The material was found in the course of a study to discredit "arsenobismite"; unfortunately it is not known when, or from where in the Ojuela mine, the "arsenobismite" specimens were collected. Kolitsch (2002) suggests that some old "carminite" specimens, if re-examined, may prove to be, at least in part, sewardite.

Siderite $FeCO_3$

Siderite occurs in veinlets in the upper parts of oxidized ore zones in the district. The species has been noted from the Ojuela mine, but the tan euhedral crystals to 1 cm described by Hoffmann (1967) and Panczner (1987) may be from any one or more of the other Mapimí-area mines.

Silver Ag

Wires and flattened plates of native silver to 1 cm have been reported from *San Juan Poniente*, associated with cerussite, anglesite and mimetite (Panczner, 1987). **Elsewhere in the district**, finely disseminated silver occurs in the oxidized lead ores of various mines; examination of polished ore sections has shown the silver to be partially replaced by a gray mineral, probably chlorargyrite (Hoffmann, 1967).

Smithsonite $ZnCO_3$

The adamite-rich *"Level Four"* of the Ojuela mine has produced mamillary plates of iridescent brown smithsonite, and Hoffmann (1967) mentions pale blue rhombic smithsonite crystals on goethite matrix, associated with colorless calcite and acicular crystals of plattnerite. The Ojuela mine's best smithsonite specimens come from the legrandite zones in *Palomes Oriente*, with legrandite, köttigite/parasymplesite, gypsum and paradamite. Smithsonite specimens from this *lugar* display white "rice grain" crystals to 5 mm, as well as water-clear compound (stepped) rhombohedrons to 1 cm. In *La Cigueña*, pseudomorphs after legrandite crystals to 4.5 cm have been found; the pseudomorphing material is a mixture of smithsonite and goethite.

Elsewhere in the district, smithsonite is found in many mines and prospects. Some gypsum crystal clusters from the **Platosa mine** are encrusted by gray to bright blue "rice grain" smithsonite crystals to 1 cm, with white hydrozincite.

Sphalerite ZnS

Pale golden brown to dark brown massive sphalerite is associated with chalcopyrite, galena, pyrite, arsenopyrite and other sulfides in the primary Mapimí ores; the alteration of sphalerite contributes to the formation of smithsonite, hemimorphite, and the characteristic suite of zinc arsenates in the Ojuela mine (Hoffmann, 1967).

Stannite Cu_2FeSnS_4

Stannite replaces sphalerite and is partially replaced by galena and bismuth in the primary ores of *Monterrey*; it appears as small grains with other sulfides (Hoffmann, 1967).

Stibiconite $Sb^{3+}Sb_2^{5+}O_6(OH)$

Stibiconite replaces stibnite in the sulfide ores of the Ojuela mine, in *America Dos* (Hoffmann, 1967). Examination of earthy stibiconite from the Ojuela mine revealed the presence of valentinite (Vitaliano and Mason, 1952), but the presence of cervantite is questionable (Hoffmann, 1967).

Elsewhere in the district, stibiconite as pseudomorphic replacements of stibnite crystals associated with bindheimite is fairly common in several mines on the western slope of the Bufa de Mapimí, and in the **San Ilario mine**, La Reina Mountain (Hoffmann, 1967).

Stibnite Sb_2S_3

Massive stibnite is found in the sulfide ores of *America Dos*; the bindheimite ores of *San Juan Poniente* are the result of complete oxidation of lead-antimony sulfides (Hoffmann, 1967).

Elsewhere in the district, complex euhedral crystals of stibnite to 1 cm have been found in the **Asterillo mine**, with calcite, barite, siderite, ankerite and quartz (Panczner, 1987).

Tennantite $(Cu,Ag,Fe,Zn)_{12}As_4S_{13}$

Tennantite is a minor constituent of the massive sulfide ores of the Ojuela and other district mines; microchemical tests showing abundant As and only minor Sb distinguish it from tetrahedrite (Hoffmann, 1967).

Tenorite $Cu^{2+}O$

Tenorite is common as an alteration coating on cuprite; it is dark blackish brown to black, with a resinous to pitchy luster (Hoffmann, 1967).

Tetrahedrite $(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$

Tetrahedrite, a minor but widespread component of the primary sulfide ores of Mapimí, is found in grains and small, irregular masses with galena, sphalerite, chalcopyrite, enargite and other primary ore minerals; spectrographic analyses of tetrahedrite grains show several percent of silver to be present (Hoffmann, 1967).

Tsumcorite $Pb(Zn,Fe^{3+})_2(AsO_4)_2(OH,H_2O)_2$

According to Mike New (personal communication, 2002), a single specimen found with the legrandite of *Plan de Ayala* contained a few microcrystals of tsumcorite; the identification was reportedly made by a mineralogist employed by Miguel Romero, working with material in the Romero collection. Unfortunately this specimen has not appeared among the portion of the Romero collection now at the University of Arizona, and there is no available documentation of the determinative work. The occurrence of tsumcorite in the Ojuela mine cannot now, therefore, be accounted more than a fairly plausible rumor.

Umangite Cu_3Se_2

Polished sections of ore from *Monterrey* show umangite to be present, associated with galena, sphalerite, bismuth and emplectite (Hoffmann, 1967).

Valentinite Sb_2O_3

Valentinite occurs in trace amounts in earthy stibiconite from the Ojuela mine (Vitaliano and Mason, 1952).

Vanadinite $Pb_5(VO_4)Cl$

Bright brownish orange crystals of vanadinite to 0.1 mm were seen on a specimen of wulfenite and calcite crystals on goethite from the Ojuela mine (Hoffmann, 1967); Panczner (1987) notes vanadinite crystals with these associations to 8 mm. Since there is vastly more arsenic than vanadium in the Ojuela ores, and mimetite can accommodate some substitution of V for As, vanadinite is consequently very rare, being found only in local areas where As is almost entirely lacking (Hoffmann's specimen showed only a trace of As).

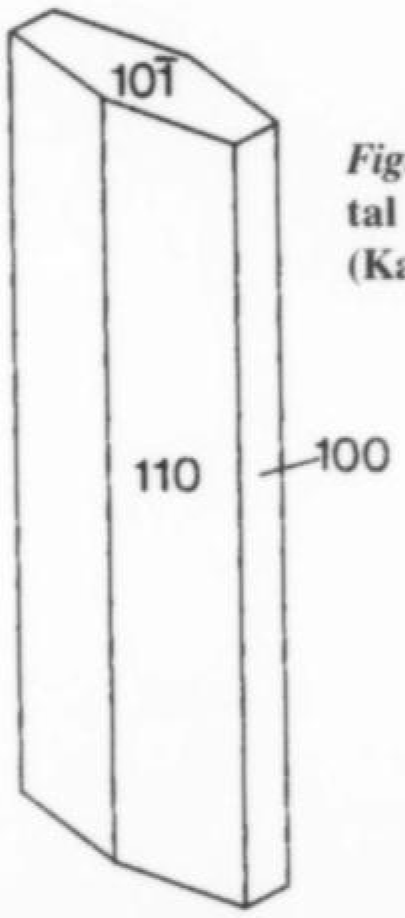
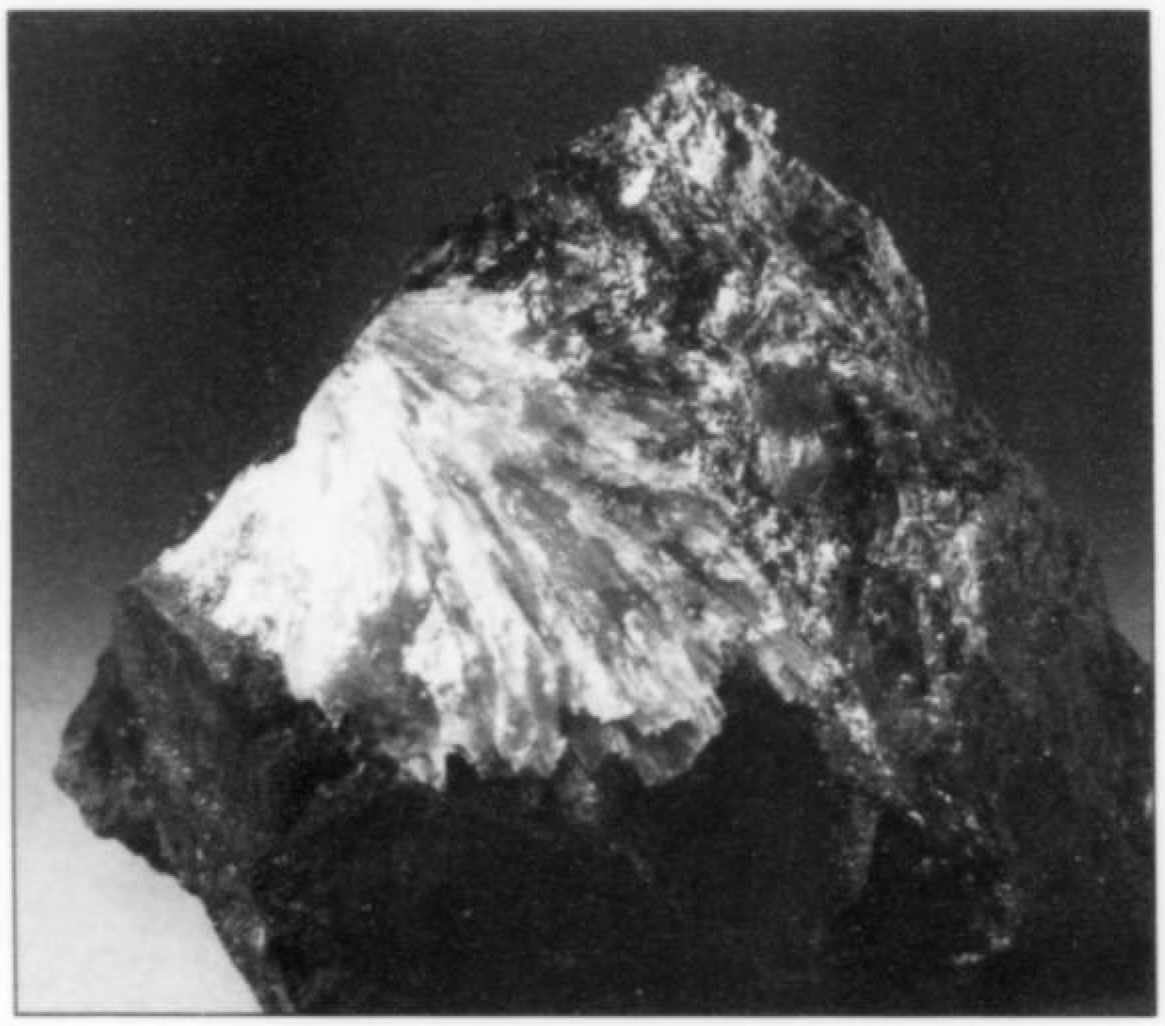


Figure 125. **Villyaellenite crystal drawing, Ojuela mine (Kampf and Ross, 1988).**

Figure 126. **Villyaellenite crystals to 4 cm, from the Ojuela mine, San Judas chimney. Los Angeles County Museum of Natural History collection; Anthony Kampf photo.**



Villyaellenite $(Mn^{2+},Ca,Zn)_5(AsO_4)_2[AsO_3(OH)]_2 \cdot 4H_2O$

Villyaellenite is the Mn end-member of a hypothetical series to sainfeldite, the Ca end-member. The studies of Kampf and Ross (1988) leave it unclear as to how Mn and Ca are ordered in the structure, and, since few intermediate members of the hypothetical series have been found, these authors question whether a complete solid substitution series in fact exists. Villyaellenite from the type locality, Ste.-Marie-aux-Mines, France, is near the midpoint of the hypothetical series, while material from the second locality, the Sterling Hill mine, New Jersey, is the pure Mn member, like the Ojuela material (Kampf and Ross, 1988). In 1997, pink microcrystals of villyaellenite lining seams in limonite were found at a fourth locality, Tierra Amarilla, Chile (Moore, 1998).

The only known specimen of villyaellenite from the Ojuela mine shows a compact spray of orange-pink prismatic crystals to 4 cm

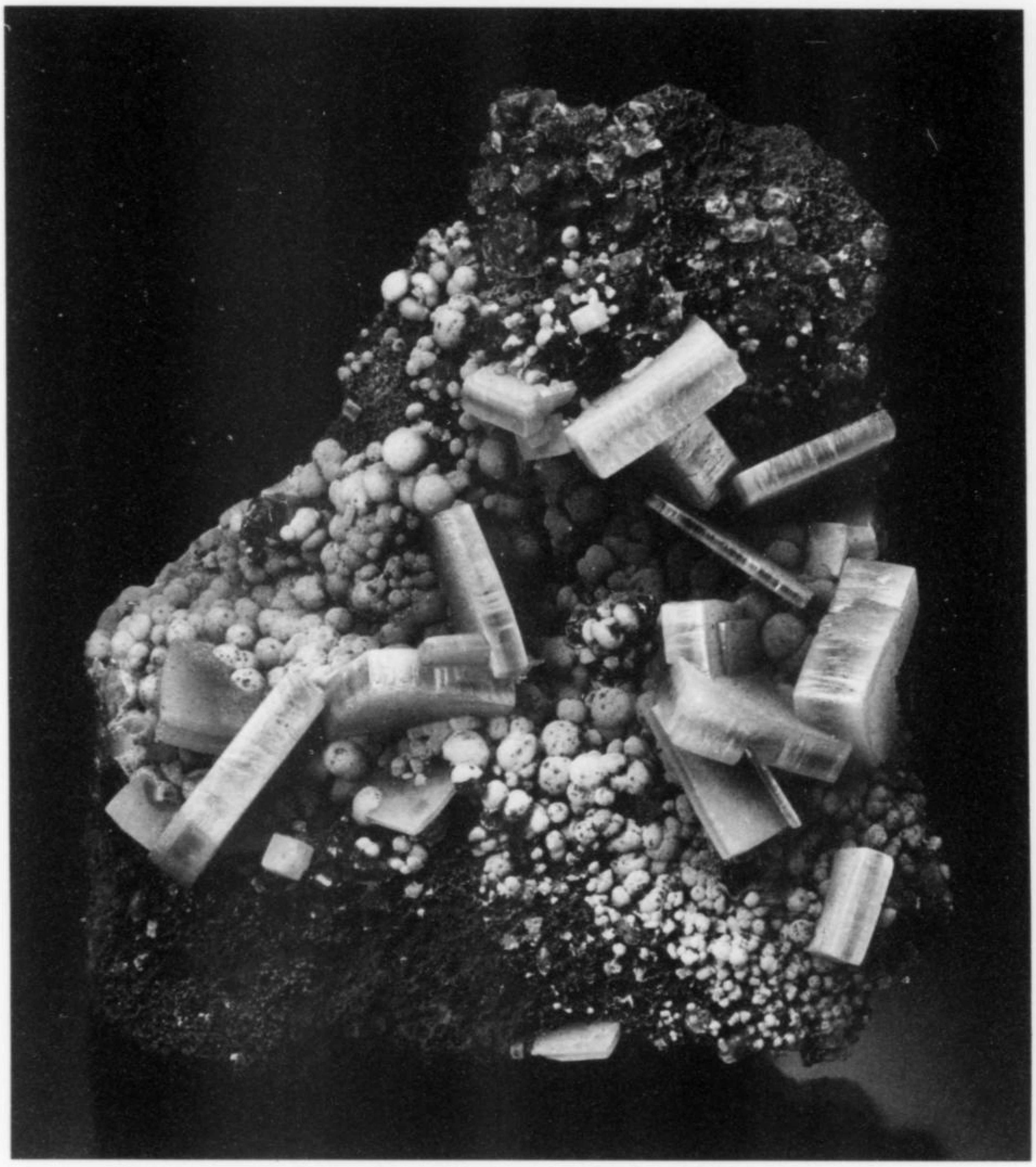


Figure 127. **Wulfenite with mimetite, 5.4 cm, from the Ojuela mine. Richard Jackson collection; Jeff Scovil photo.**

long, in an aureole of chalcophanite in a vug in goethite, associated with ogdensburgite, arseniosiderite, and adamite. The Ojuela mine villyaellenite specimen was collected by John Whitmire in 1981 from *San Judas*, in the pocket zone which yielded the famous purple adamite, in a paragenesis including ogdensburgite, the other new species described from this occurrence. This (so far) unique specimen is in the collection of the Los Angeles County Museum of Natural History, and may be seen there on public display in the mineral hall.

Woodruffite $(Zn, Mn^{2+})Mn_3^{4+}O_7 \cdot 1\text{–}2H_2O$

Neither Hoffmann (1967) nor Panczner (1987) lists woodruffite among known species from the Mapimí district, but Mapimí very probably is the source of some woodruffite specimens alleged to have come from the Potosí mine, in the Santa Eulalia district, Chihuahua. These specimens, offered at the 1995 Tucson Show by Arizona dealer Dave Shannon, are cabinet-size matrix pieces of red-brown iron oxides with cavities lined by 6-mm spheres of radiating needles of woodruffite, with tiny adamite crystals. Dr. Miguel Romero testified at the time that he had seen similar material from the Mapimí district, and the specimens had been originally sold from a town near Mapimí, so the revised locality attribution is very likely correct (Megaw, 1995).

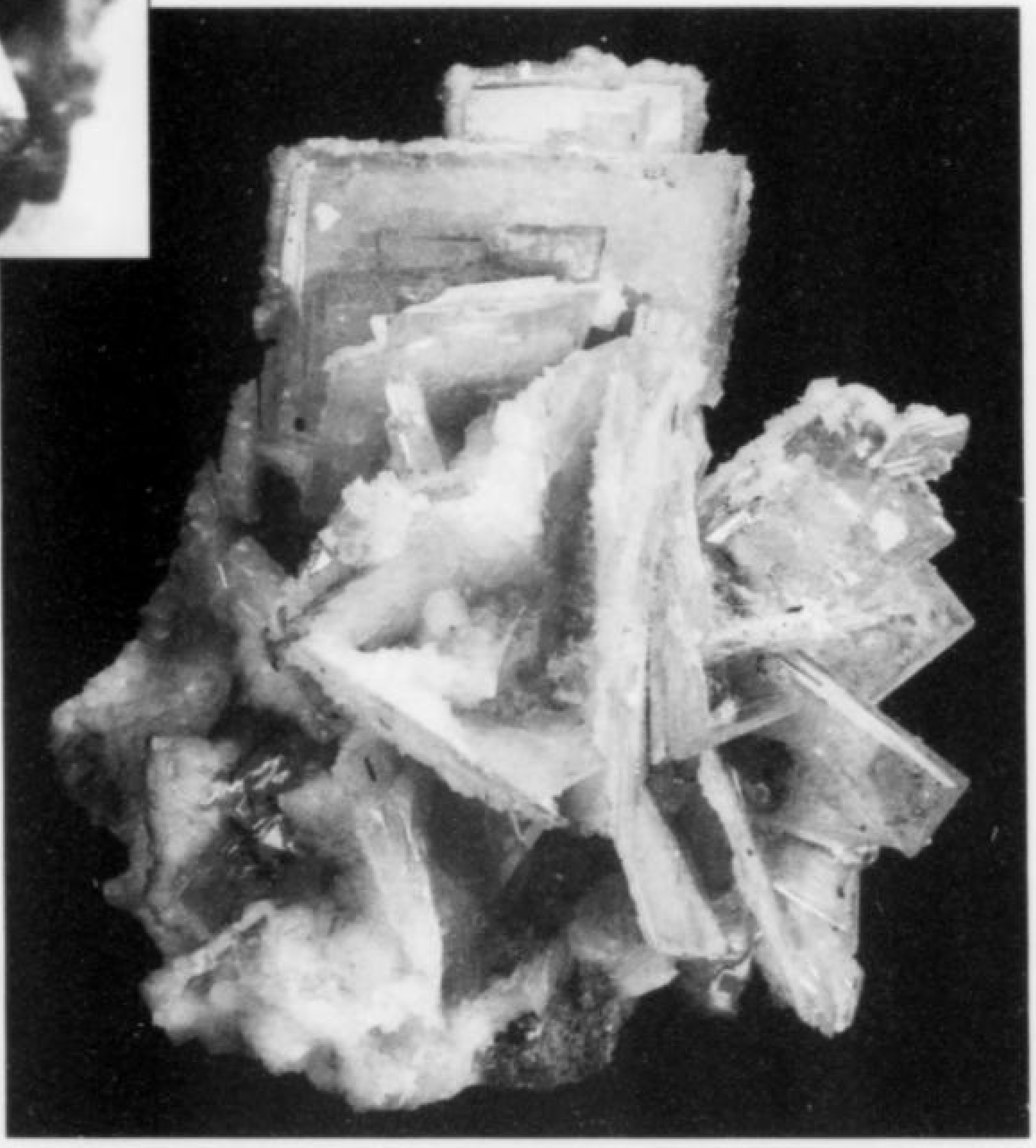
Wulfenite $PbMoO_4$

Although the Ojuela mine may not be the equal of other world-class localities for wulfenite in Mexico, some very fine specimens, with crystals to 5 cm, have been produced (Panczner, 1987). Wulfenite at Ojuela is widely distributed in the oxidized lead ores, associated with mimetite, duftite, bindheimite, cerussite, hemimorphite, aurichalcite, adamite, plattnerite and calcite (Hoffmann, 1967). The color range is very wide, but the most common hues are yellow, orange, and brown. Stambaugh (2002) notes "black" wulfenite, stained surficially by an unknown metallic mineral, and very thin, transparent, pale green wulfenite crystals emplanted on green mimetite.

Pale yellow tabular crystals associated with calcite, mimetite and plattnerite (Johnson, 1962) came in the 1960's from *America*

Figure 128. Wulfenite crystals to 9 mm on mimetite from the Ojuela mine, Campana *lugar*, collected in 2003. Thomas Moore collection; Wendell Wilson photo.

Figure 129. Wulfenite crystal cluster with calcite, 5.3 cm, from the Ojuela mine. Kerith Graeber collection; Jeff Scovil photo.



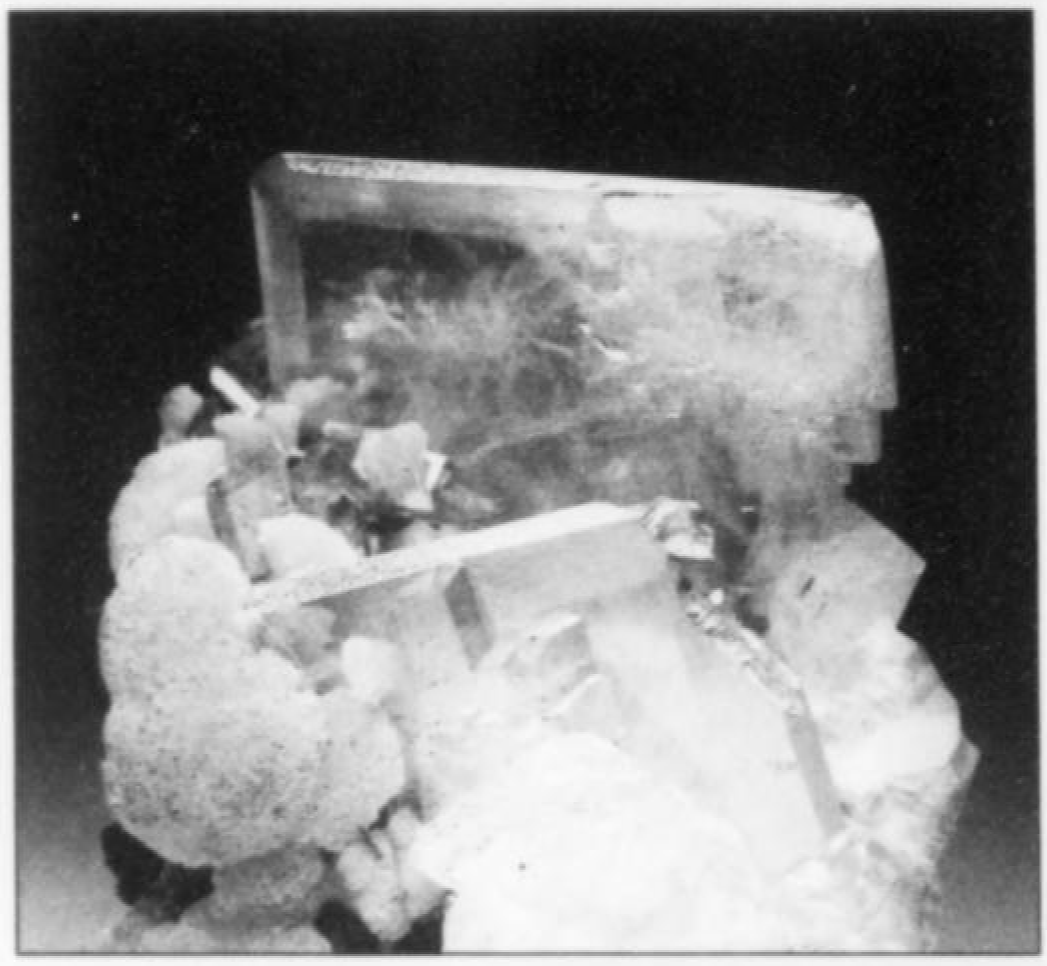


Figure 130. Wulfenite crystal, 1.7 cm, on mimetite and calcite, from the Ojuela mine. University of Arizona Mineral Museum collection; Wendell Wilson photo.

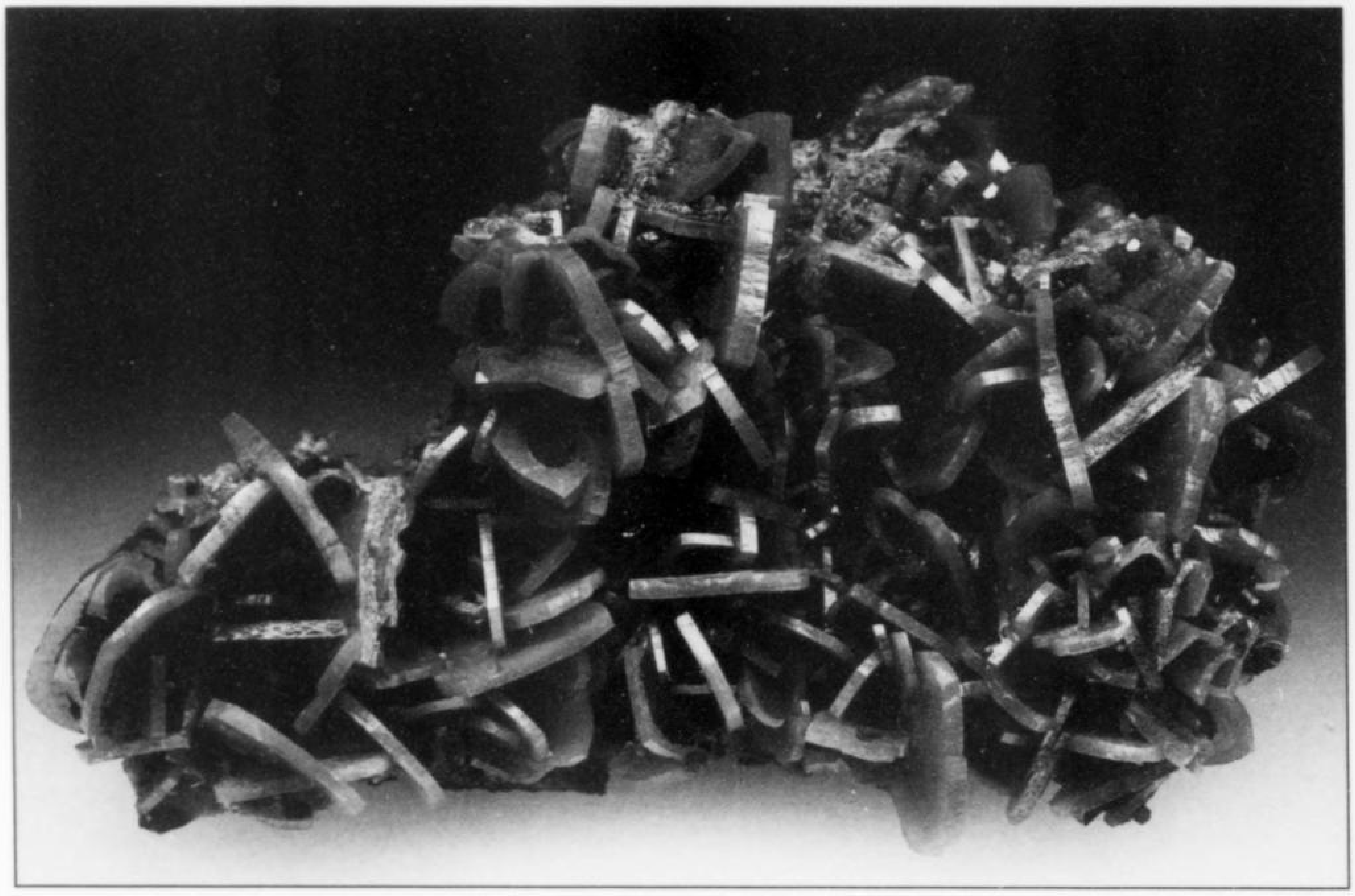


Figure 131. Wulfenite crystals with mimetite, 10.5 cm, from the Ojuela mine. Miguel Romero collection, now in the University of Arizona Mineral Museum; Wendell Wilson photo.

Table **2 Minerals identified from the Ojuela mine**

Elements	
Bismuth	Bi
Copper	Cu
Gold	Au
Silver	Ag
Sulfides, Selenides	
Arsenopyrite	$FeAsS$
Berzelianite	Cu_2Se
Bismuthinite	Bi_2S_3
Bornite	Cu_5FeS_4
Chalcopyrite	$CuFeS_2$
Clausthalite	$PbSe$
Covellite	CuS
Galena	PbS
Marcasite	FeS_2
Molybdenite	MoS_2
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$, $x = 0–0.17$
Realgar	AsS
Sphalerite	ZnS
Stannite	Cu_2FeSnS_4
Umangite	Cu_3Se_2
Sulfosalts	
Boulangerite	$Pb_5Sb_4S_{11}$
Emplectite	$CuBiS_2$
Enargite	Cu_3AsS_4
Jamesonite	$Pb_4FeSb_6S_{14}$
Pyrargyrite	Ag_3SbS_3
Tennantite	$(Cu,Ag,Fe,Zn)_{12}As_4S_{13}$
Tetrahedrite	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$
Halides	
Chlorargyrite	$Ag(Cl,Br)$
Fluorite	CaF_2
Nantokite	$CuCl$
Oxides	
Bindheimite	$Pb_2Sb_2O_6(O,OH)$
Cassiterite	SnO_2
Chalcophanite	$(Zn,Fe^{2+}Mn^{3+})Mn_3^{4+}O_7\cdot 3H_2O$
Cryptomelane	$K(Mn^{4+}Mn^{2+})_8O_{16}$
Cuprite	Cu_2O
Delafossite	$Cu^{1+}Fe^{3+}O_2$
Feitknechtite	$\alpha\text{-}Mn^{3+}O(OH)$
Goethite	$\alpha\text{-}Fe^{3+}O(OH)$
Groutite	$Mn^{3+}O(OH)$
Hausmannite	$Mn^{2+}Mn_2^{3+}O_4$
Hematite	Fe_2O_3
Hydrohetaerolite	$Zn_2Mn_4^{3+}O_8\cdot H_2O$
Lepidocrocite	$\gamma\text{-}Fe^{3+}O(OH)$
Litharge	PbO
Magnetite	$Fe^{2+}Fe_2^{3+}O_4$
Minium	$Pb_2^{2+}Pb^{4+}O_4$
Murdochite	$PbCu_6^{2+}O_{8-x}(Cl,Br)_{2x}$, $x \leq 0.5$
Plattnerite	PbO_2
Pyrolusite	$Mn^{4+}O_2$
Ramsdellite	$Mn^{4+}O_2$
Scrutinyite	$\alpha\text{-}PbO_2$
Stibiconite	$Sb^{3+}Sb_2^{5+}O_6(OH)$
Tenorite	$Cu^{2+}O$
Valentinite	Sb_2O_3
Carbonates	
Ankerite	$Ca(Fe^{2+},Mg,Mn)(CO_3)_2$
Aragonite	$CaCO_3$
Aurichalcite	$(Zn,Cu^{2+})_5(CO_3)_2(OH)_6$
Azurite	$Cu_3^{2+}(CO_3)_2(OH)_2$
Calcite	$CaCO_3$
Cerussite	$PbCO_3$
Dolomite	$CaMg(CO_3)_2$
Hydrozincite	$Zn_5(CO_3)_2(OH)_6$
Malachite	$Cu_2^{2+}(CO_3)(OH)_2$
Rosasite	$(Cu^{2+},Zn)_2(CO_3)(OH)_2$
Siderite	$FeCO_3$
Smithsonite	$ZnCO_3$
Zincrosasite	$(Zn,Cu^{2+})_2(CO_3)(OH)_2$
Vanadates	
Descloizite	$PbZn(VO_4)(OH)$
Vanadinite	$Pb_5(VO_4)Cl$
Molybdates	
Ferrimolybdite	$Fe_2^{3+}(Mo^{6+}O_4)_3\cdot 8H_2O$ (?)
Wulfenite	$PbMoO_4$
Silicates	
Diopside	$CaMgSi_2O_6$
Hemimorphite	$Zn_4Si_2O_7(OH)_2\cdot H_2O$
Kaolinite	$Al_2Si_2O_5(OH)_4$
Quartz	SiO_2
Sauconite	$Na_{0.3}Zn_3(Si,Al)_4O_{10}(OH)_2\cdot 4H_2O$
Sulfates	
Anglesite	$PbSO_4$
Barite	$BaSO_4$
Brochantite	$Cu_4^{2+}(SO_4)(OH)_6$
Celestine	$SrSO_4$
Gypsum	$CaSO_4\cdot 2H_2O$
Jarosite	$K_2Fe_6^{3+}(SO_4)_4(OH)_{12}$
Melanterite	$Fe^{2+}SO_4\cdot 7H_2O$
Plumbojarosite	$PbFe_6^{3+}(SO_4)_4(OH)_{12}$
Phosphates	
Apatite Group	$Ca_5(PO_4)_3(F,Cl,OH)$
Libethenite	$Cu^{2+}{}_2(PO_4)(OH)$
Arsenates	
Adamite	$Zn_2(AsO_4)(OH)$
Arsendescloizite	$PbZn(AsO_4)(OH)$
Arseniosiderite	$Ca_2Fe_3^{3+}(AsO_4)_3O_2\cdot 3H_2O$
Austinite	$CaZn(AsO_4)(OH)$
Bayldonite	$PbCu_3(AsO_4)_2(OH)_2\cdot H_2O$
Beudantite	$PbFe_3^{3+}(AsO_4)(SO_4)(OH)_6$
Carminite	$PbFe_2^{3+}(AsO_4)_2(OH)_2$
Chenevixite	$Cu_2^{2+}Fe_2^{3+}(AsO_4)_2(OH)_4\cdot H_2O$
Conichalcite	$CaCu^{2+}(AsO_4)(OH)$
Duftite	$(Pb,Ca)Cu(AsO_4)(OH)$
Dussertite	$BaFe_3^{3+}(AsO_4)_2(OH)_5$
Hedyphane	$Pb_3Ca_2(AsO_4)_3Cl$
Köttigite-Parasymplesite	$Zn_3(AsO_4)_2\cdot 8H_2O - Fe_3^{2+}(AsO_4)_2\cdot 8H_2O$
Legrandite	$Zn_2(AsO_4)(OH)\cdot H_2O$
Lotharmeyerite	$Ca(Mn^{3+},Zn)_2(AsO_4)_2(OH,H_2O)_2$
Manganlotharmeyerite	$Ca(Mn^{3+},\square,Mg)_2\{AsO_4,[AsO_2(OH)_2]\}_2(OH,H_2O)_2$
Mapimite	$Zn_2Fe_3^{3+}(AsO_4)_3(OH)_4\cdot 10H_2O$
Metaköttigite	$(Zn,Fe^{3+},Fe^{2+})_3(AsO_4)_2\cdot 8(H_2O,OH)$
Mimetite-Pyromorphite	$Pb_5(AsO_4,PO_4)_3Cl$
Mn-analog of Arseniosiderite	$Ca_2Mn^{3+}{}_3(AsO_4)_3O_2\cdot 3H_2O$
Ogdensburgite	$Ca_2(Zn,Mn^{2+})Fe_4^{3+}(AsO_4)_4(OH)_6\cdot 6H_2O$
Ojuelaite	$ZnFe_2^{3+}(AsO_4)_2\cdot 4H_2O$
Paradamite	$Zn_2(AsO_4)(OH)$
Pharmacosiderite	$Kfe_4^{3+}(AsO_4)_3(OH)_4\cdot 6–7H_2O$
Scorodite	$Fe^{3+}AsO_4\cdot 2H_2O$
Segnitite	$PbFe_3^{3+}H(AsO_4)_2(OH)_6$
Sewardite	$CaFe_2^{3+}(AsO_4)_2(OH)_2$
Tsumcorite (?)	$Pb(Zn,Fe^{3+})_2(AsO_4)_2(OH,H_2O)_2$
Villyaellenite	$(Mn^{2+},Ca,Zn)_5(AsO_4)_2[AsO_3(OH)]_2\cdot 4H_2O$

Poniente, and bright red wulfenite crystals which owe their color to inclusions of litharge (Panczner, 1987) have occasionally been found.

Of the two chief wulfenite crystal habits, tabular crystals are the more common, being known in considerable variations of color and thickness from many scattered sites in the Ojuela mine. Bipyramidal wulfenite crystals reach 2 cm and are usually dark orange-brown (Hoffmann, 1967). On his website, Stambaugh (2002) pictures a specimen with yellow-brown wulfenite in simple tetragonal prisms with flat terminations, to 7 mm, on mimetite.

A collecting area on Level 5 of the Ojuela mine (which is usually under water) produces, in rare dry seasons, thick-tabular to almost blocky yellow-brown wulfenite crystals with "sandwich" zoning, to 1.5 cm across; their matrix is not the usual goethite but a white, dolomitized limestone. These wulfenite specimens appeared around 1980 and again in 1993 (Megaw, 1993).

Also on Level 5, in *Campana*, a series of pockets lined with green mimetite was uncovered in 1968, and almost a ton of specimens were sold by the co-operative's miners to Parser Mineral Company; these specimens show bright yellow-orange crystals to 5 cm on mammillary green mimetite pocket linings. In 1981, about 200 good specimens of the same type emerged from *Campana*; a very fine piece from this find resides in the Cal and Kerith Graeber collection, and another (assembled) specimen, once in the Tom McKee collection, is illustrated on page 131 of Bancroft's *Gem and Crystal Treasures* (1984). For sidelights on this 1981 discovery see Mike New's story in the sidebar "Purple Adamite Tales."

As of this writing (spring 2003), *Campana* is once again producing substantial numbers of good, new wulfenite specimens, this time from Level 7. The crystals are bright brownish orange, commonly quite lustrous, and in some cases gemmy; so far they have reached 2.5 cm across, and range in habit from very thin-tabular to thick, almost blocky. Their goethite matrix is very vuggy and friable; in its recesses, lined by satiny green botryoidal mimetite, wulfenite crystals perch singly or form small groups with translucent white rhombohedral calcite crystals to 1 cm.

A miniature-size Ojuela mine specimen in the Miguel Romero collection at the University of Arizona is a delicate cluster of very thin wulfenite crystals coated with dense drusy quartz, and pseudomorphically replaced in part by quartz.

Specimens in the collections of Charles S. Thompson and Cal and Kerith Graeber show sharp-cornered, fairly thin, lustrous, translucent to transparent, canary-yellow crystals to 3 or 4 cm on an edge, partially to completely covered by fine-grained snow-white calcite.

Elsewhere in the district, wulfenite microcrystals have been found in many small mines and prospects (Peter Megaw, personal communication, 2003).

Zincrosasite $(Zn,Cu^{2+})_2(CO_3)(OH)_2$

Pale blue to whitish, botryoidal crusts of zincrosasite with radial-fibrous structure occur in the Ojuela mine (McGowan, 2000).

Acknowledgments

Many thanks to Mike New of Top Gem Minerals in Tucson for allowing me to accompany him on a visit to the Ojuela mine in 2002, and to Felix Esquivel for sharing his "family" pictures of the great legrandites he found at the Ojuela mine in 1977. Peter Megaw, Mike New, and, of course, Wendell Wilson all kindly reviewed the entire manuscript, and Victor Hoffmann and Charlie Thompson provided valuable information. Joe Kielbaso loaned the big photo of the Ojuela mine scene shown at the front of this issue, and Brad and Star Van Scriver (*Heliodor*) generously loaned copy photographs which their late son and brother, Curt Van Scriver, had made many years ago from originals in the Mapimí town museum. I would also like to thank Jeff Scovil and Wendell Wilson for providing much of the specimen photography, and Wendell Wilson for help with the maps of the mine workings. Terry Wallace and Shirley Wetmore of the University of Arizona Mineral Museum granted access to the fine Ojuela mine specimens there, most notably those from the extraordinary collection of the late Miguel Romero. I greatly appreciate the edification supplied by Katie Griffith and Manuel Lopez in Mexico, and the logistical help of Rubén Avila. In the U.S., Terry Stambaugh, Dawn Minette, Gene Wright, Charlie Thompson and Cal and Kerith Graeber were generous in making available specimens from their collections for examination and photography.

I especially wish to thank the Mexican miners—and the amazingly knowledgeable and remindful Mike New—for furnishing much otherwise irretrievable data on specimen discoveries from the last few decades in various Ojuela mine *lugares*, as presented in the Minerals section. Chief miner Federico Salas Alvarado (shown in Fig. 8) was unfortunately killed in a car crash in July 2003, as this issue was going to press. The other miners, all presently at work in the mine, include Bernardino Cortes Almarez, Antonio Cortes Almarez, Pedro Perez Martinez, Gerardo Cordero Martinez, Miguel Gamboa Espinoza, Lazaro de Anda Barraza (Top Gem's chief agent), Lorenzo Pecina Sifuentes (vice-president of the cooperative), Eduardo Cordova Gomez (president of the cooperative), and Manuel Gardea Garcia. May *La India*, she of the Great Sleeping Face, keep you well.

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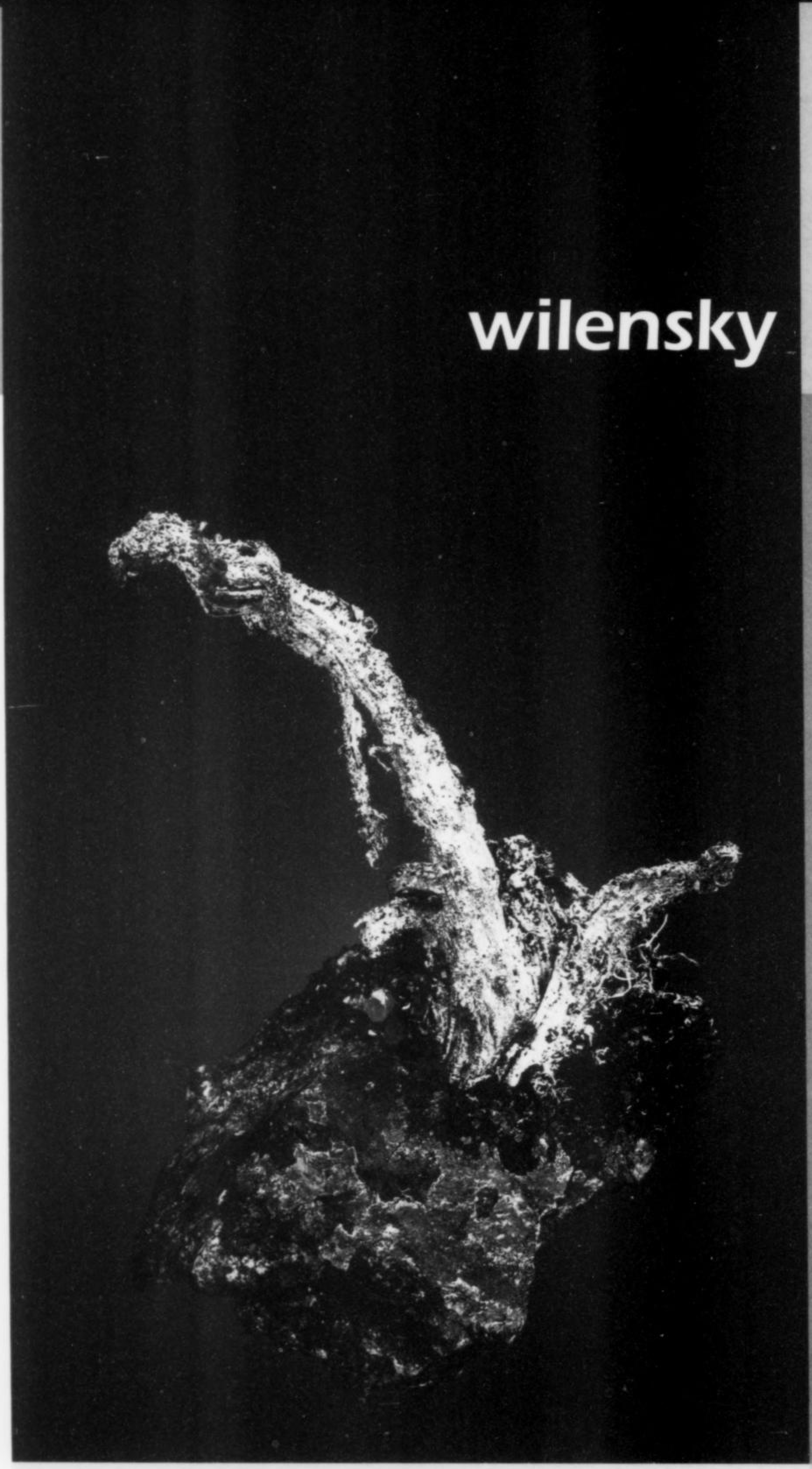
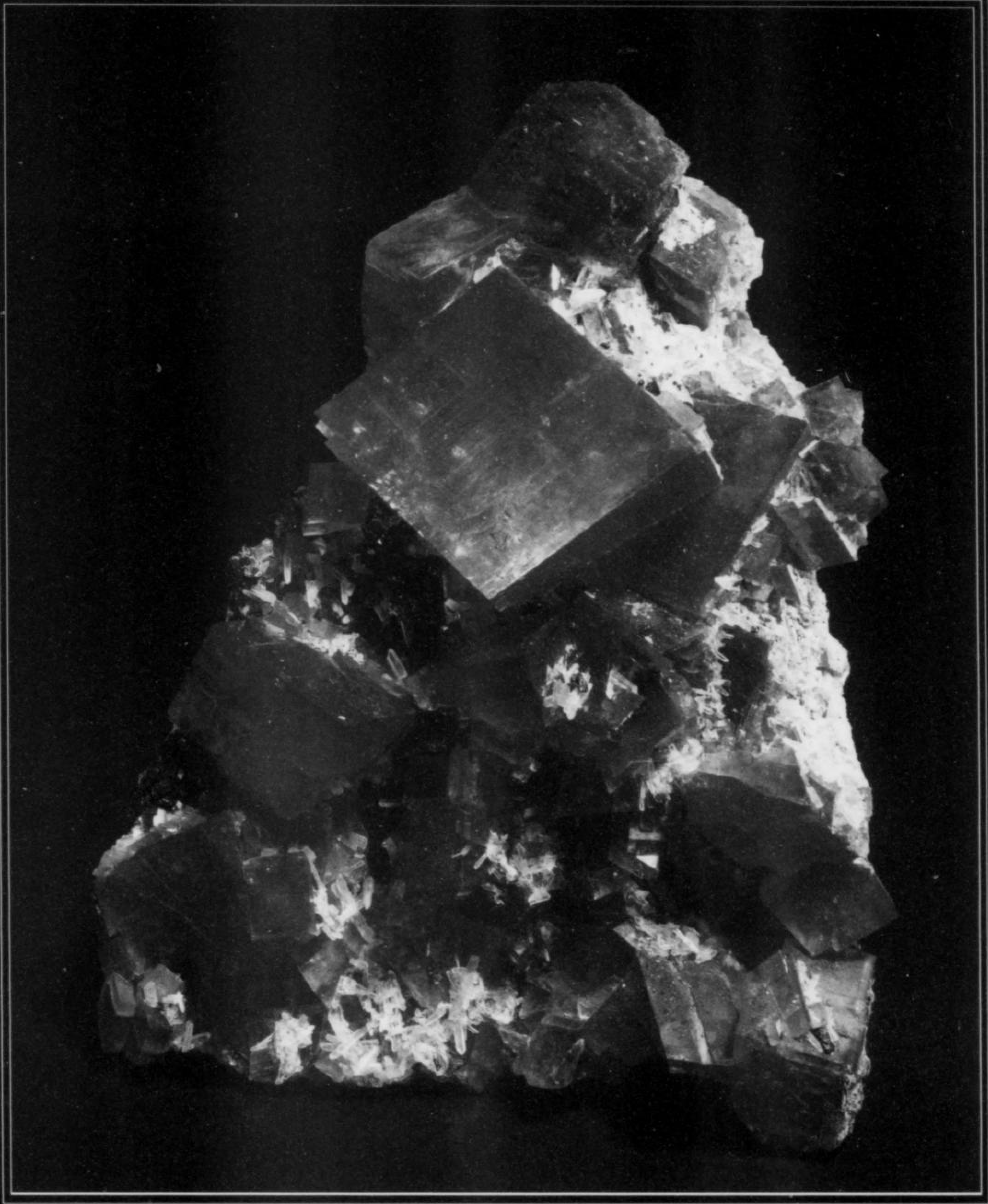
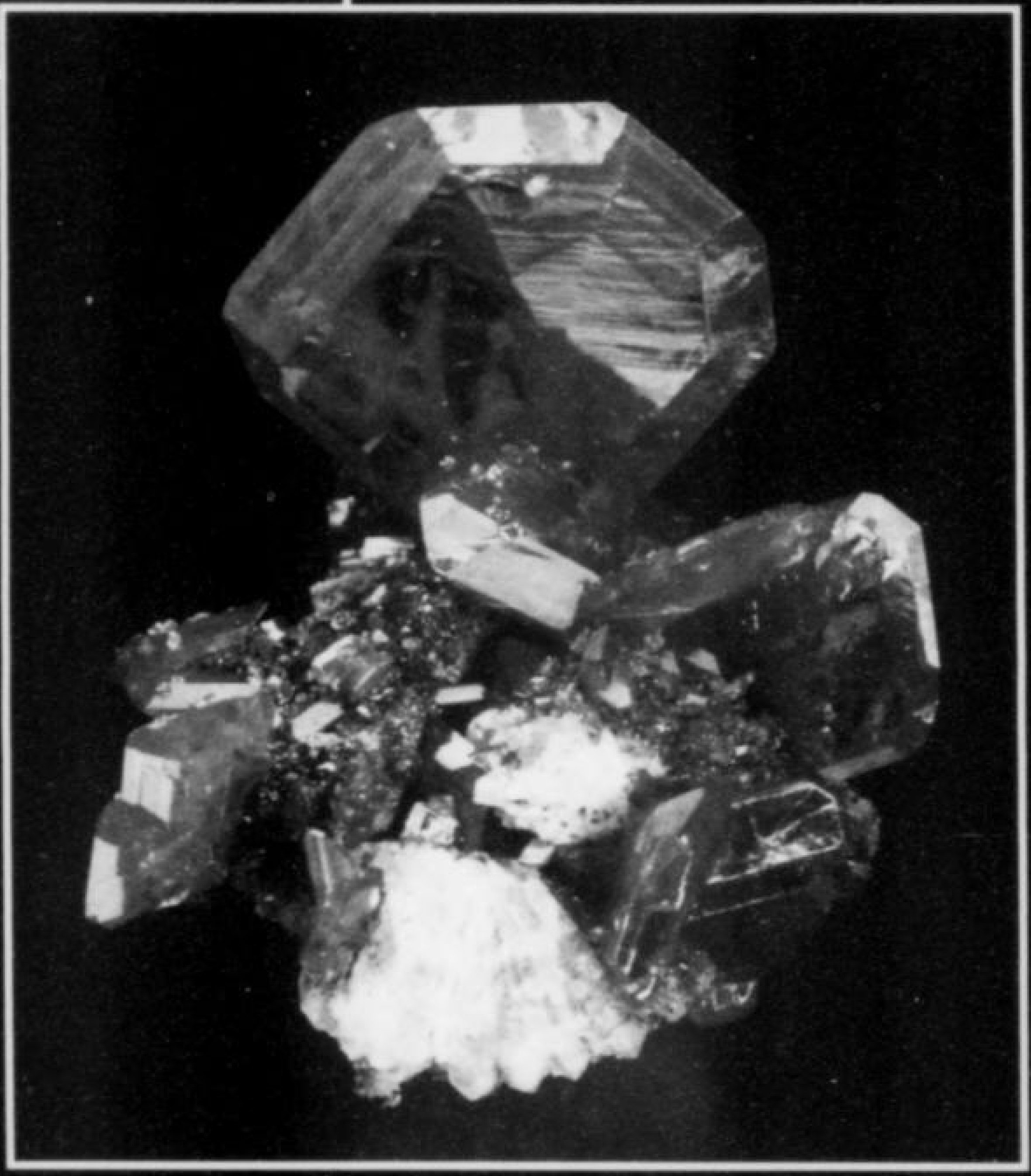
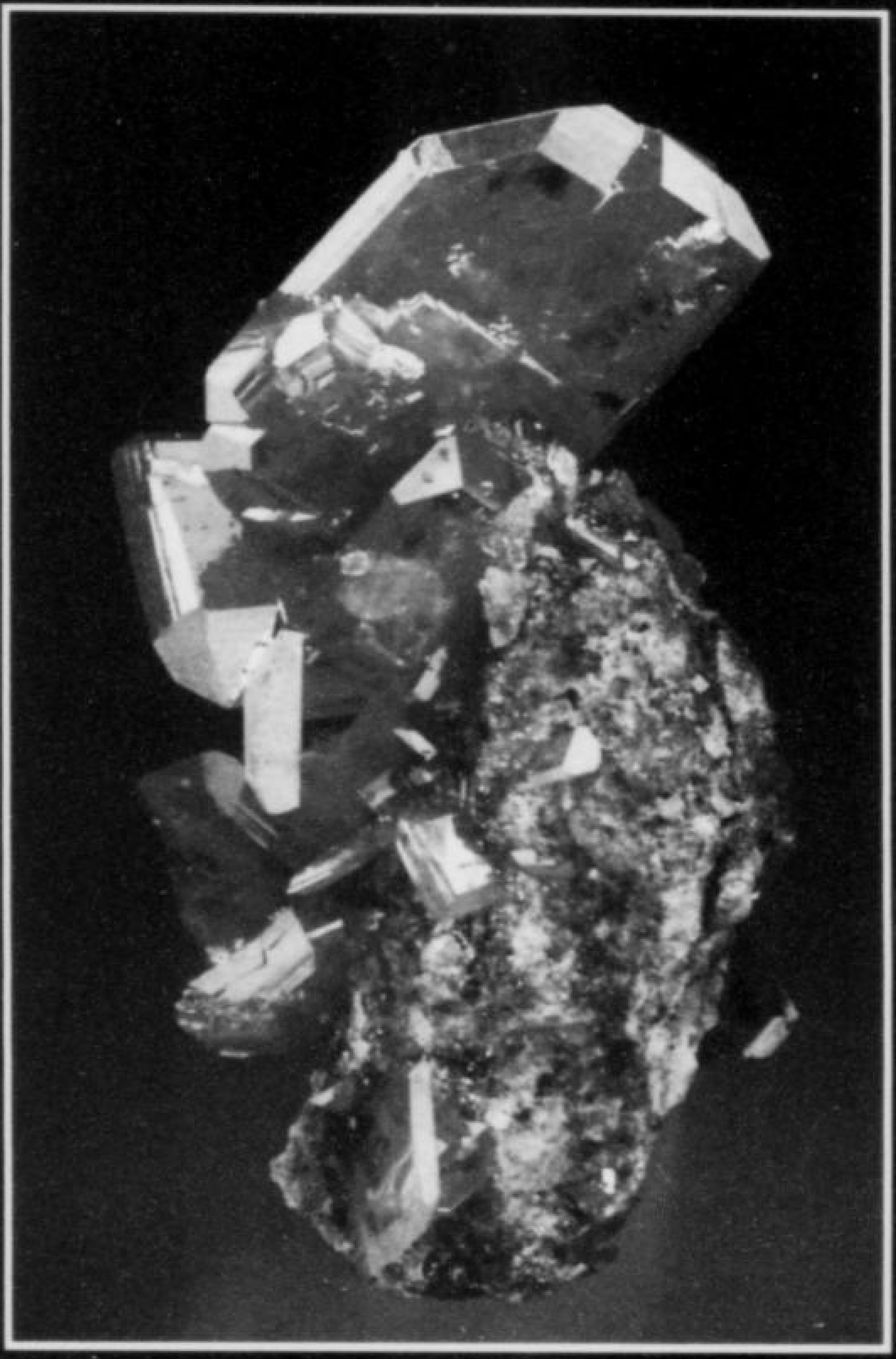
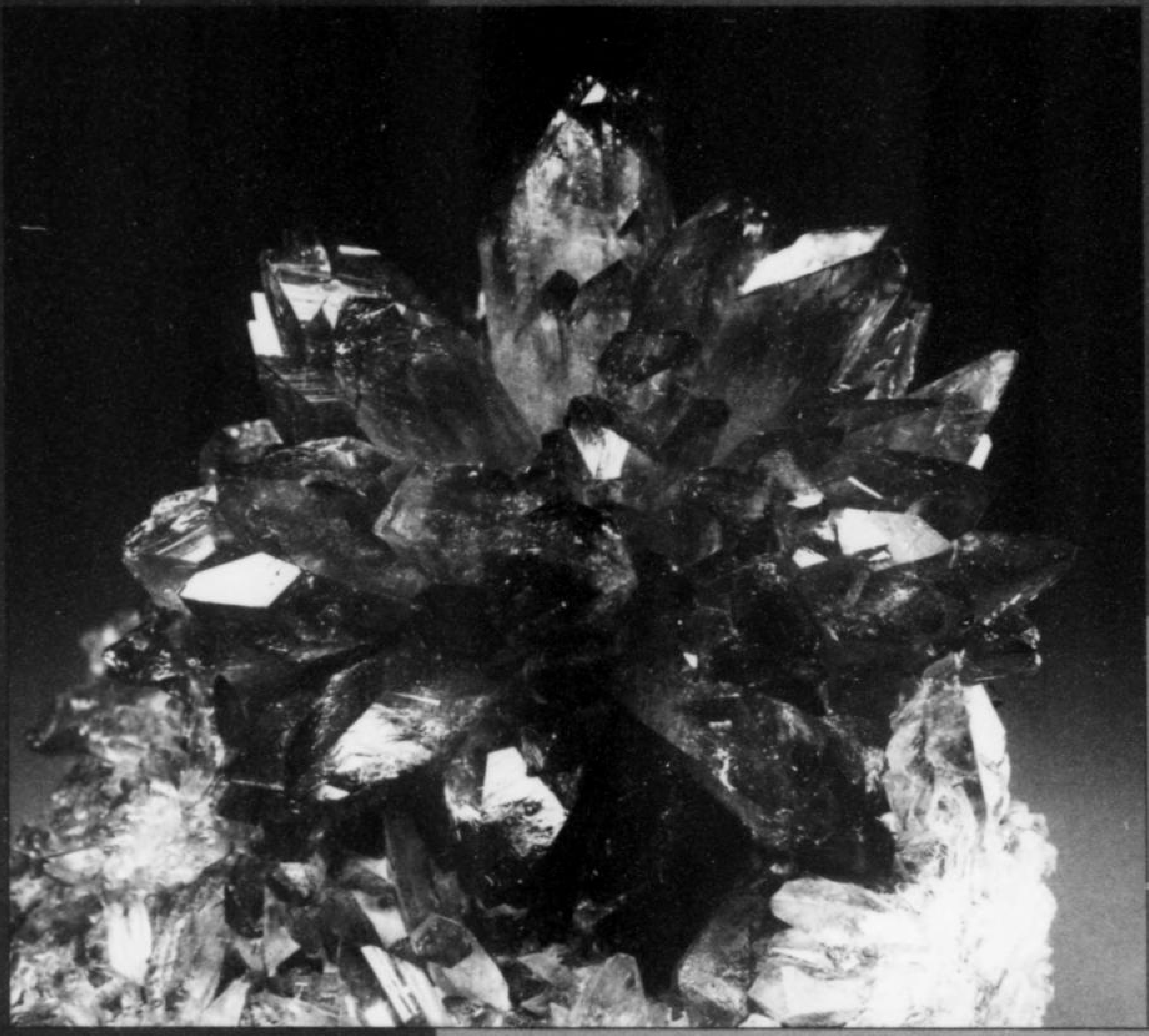


Silver with Rhodochrosite, 12.2 cm, Uchucchaqua, Peru. Jeff Scovil photo.









Creedite, 5.2 cm, from Akchatau, Kazakhstan.
Wendell Wilson photo.

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Jeff Scovil Photo

William Severance Collection

Azurite, a single complex crystal 4 cm tall
Tsumeb mine
Tsumeb, Namibia

From Wilhelm Maucher to George S. Vaux, Jr. (1927)

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e-mail: akampf@nhm.org
Collections Manager:
Dorothy L. Ettensohn
Tel: (213) 763-3327
e-mail: dettenso@nhm.org
900 Exposition Blvd.
Los Angeles, CA 90007
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The Gem and Mineral Council

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e-mail: mineralcurator@sierratel.com
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Mariposa, CA 95338
Mailing Address:
P.O. Box 1192
Mariposa, CA 95338
Hours: 10–6 Daily (May–Sept.)
10–4 Wÿ¥.–Mon. (Oct–Apr.)
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Tel: (602) 255-3795
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Phoenix, AZ 85007
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Specialty: Arizona minerals

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Curator: Thomas J. Campbell
Tel: (605) 718-2288
South Dakota School of Mines & Technology
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Rapid City, SD 57701-3995

New Mexico Bureau of Mines & Mineral Resources—Mineral Museum

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E-Mail: vwlueth@nmt.edu
Fax: (505) 835-6333
Associate Curator: Robert Eveleth
Tel: (505) 835-5325
E-mail: beveleth@gis.nmt.edu
New Mexico Tech,
801 Leroy Place
Socorro, NM 87801
Hours: 8–5 M–F, 10–3 Sat., Sun
Specialties: New Mexico minerals, mining artifacts, worldwide minerals

Penn State Earth & Mineral Sciences Museum

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Tel: (814) 865-6427
E-mail: sicree@geosc.psu.edu
Steidle Building
University Park
State College, PA 16802
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D-59 MIDC, Malegaon, **Sinnar**, Nashik 422 103 India
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Arizona-SonoraDesert Museum

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E-mail: adomitrovic@desertmuseum.org
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Tucson, AZ 85743-8918
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Specialty: Arizona minerals

Pacific Museum of the Earth

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E-mail: kparker@ubc.ca
Dept. of Earth and Ocean Sciences
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6339 Stores Rd.
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U.S. National Museum of Natural History (Smithsonian Institution)

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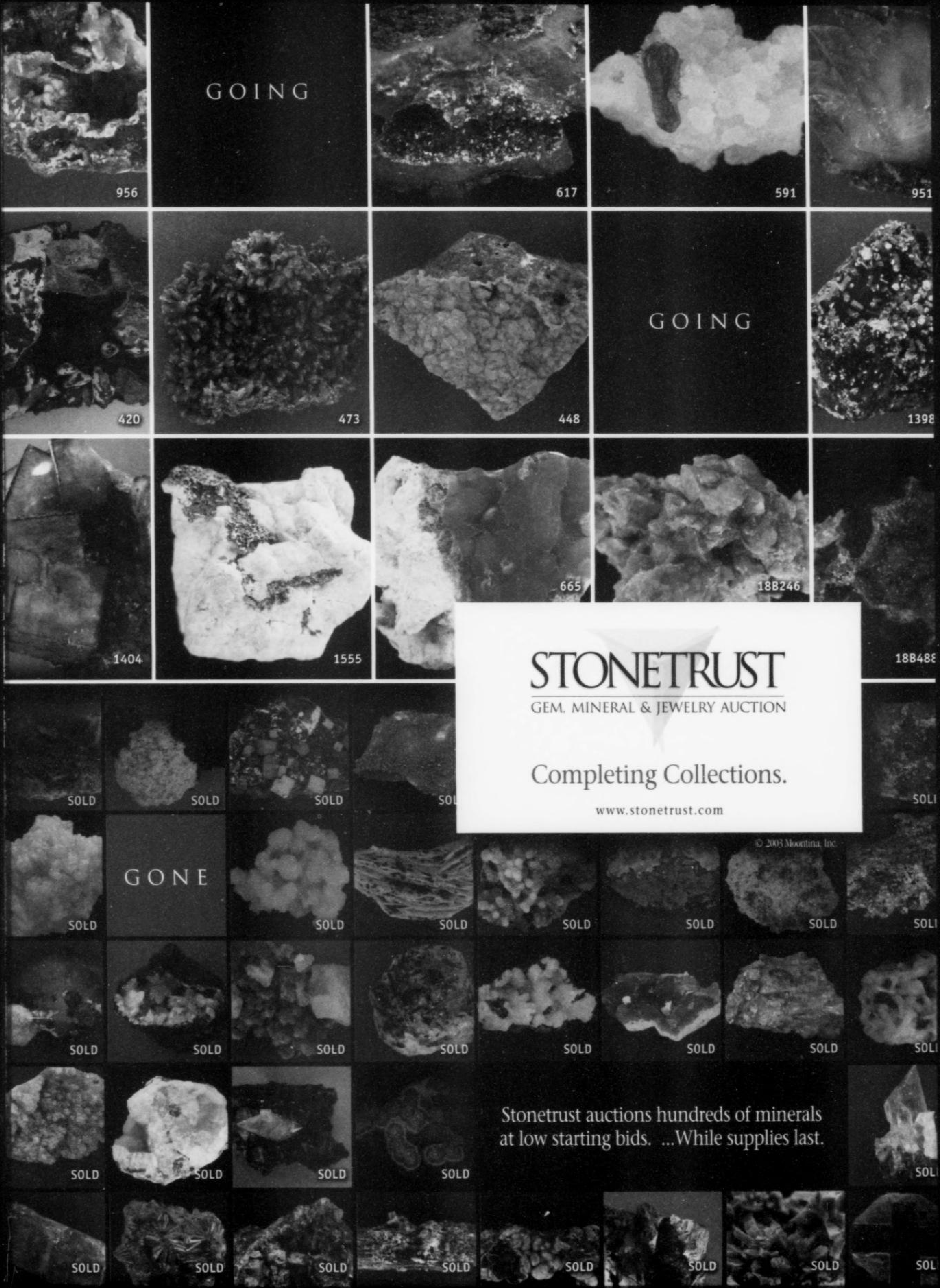
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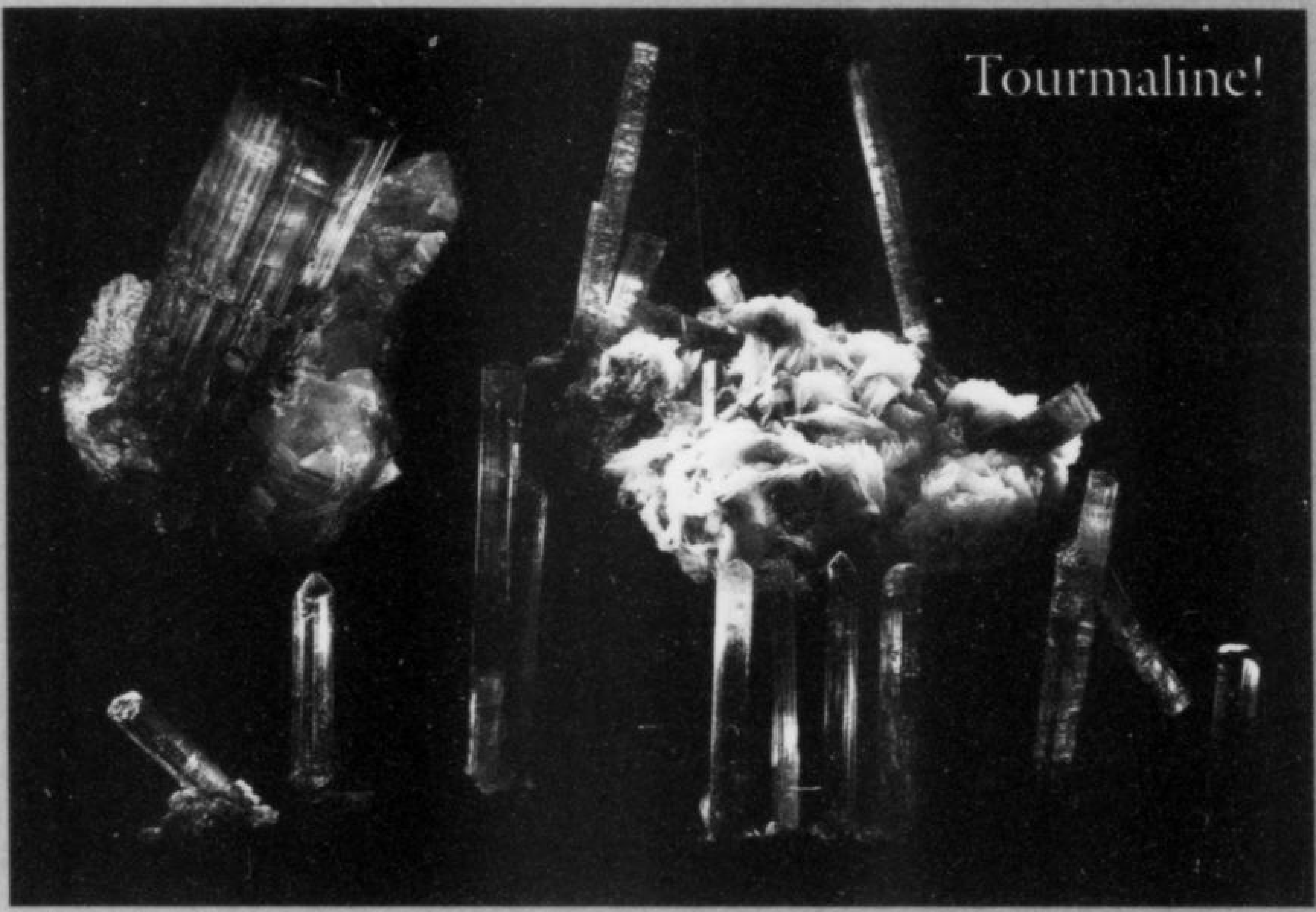
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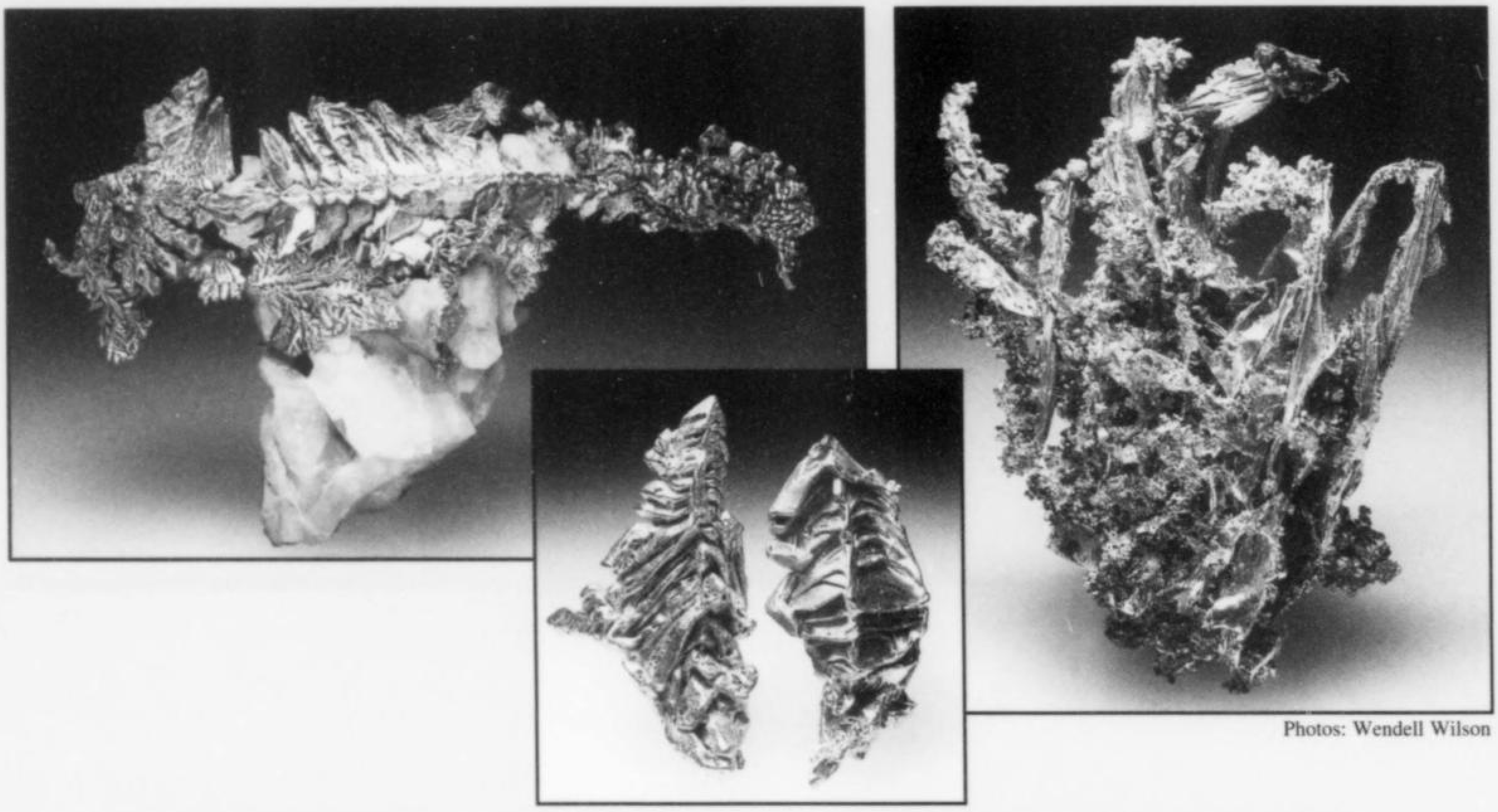
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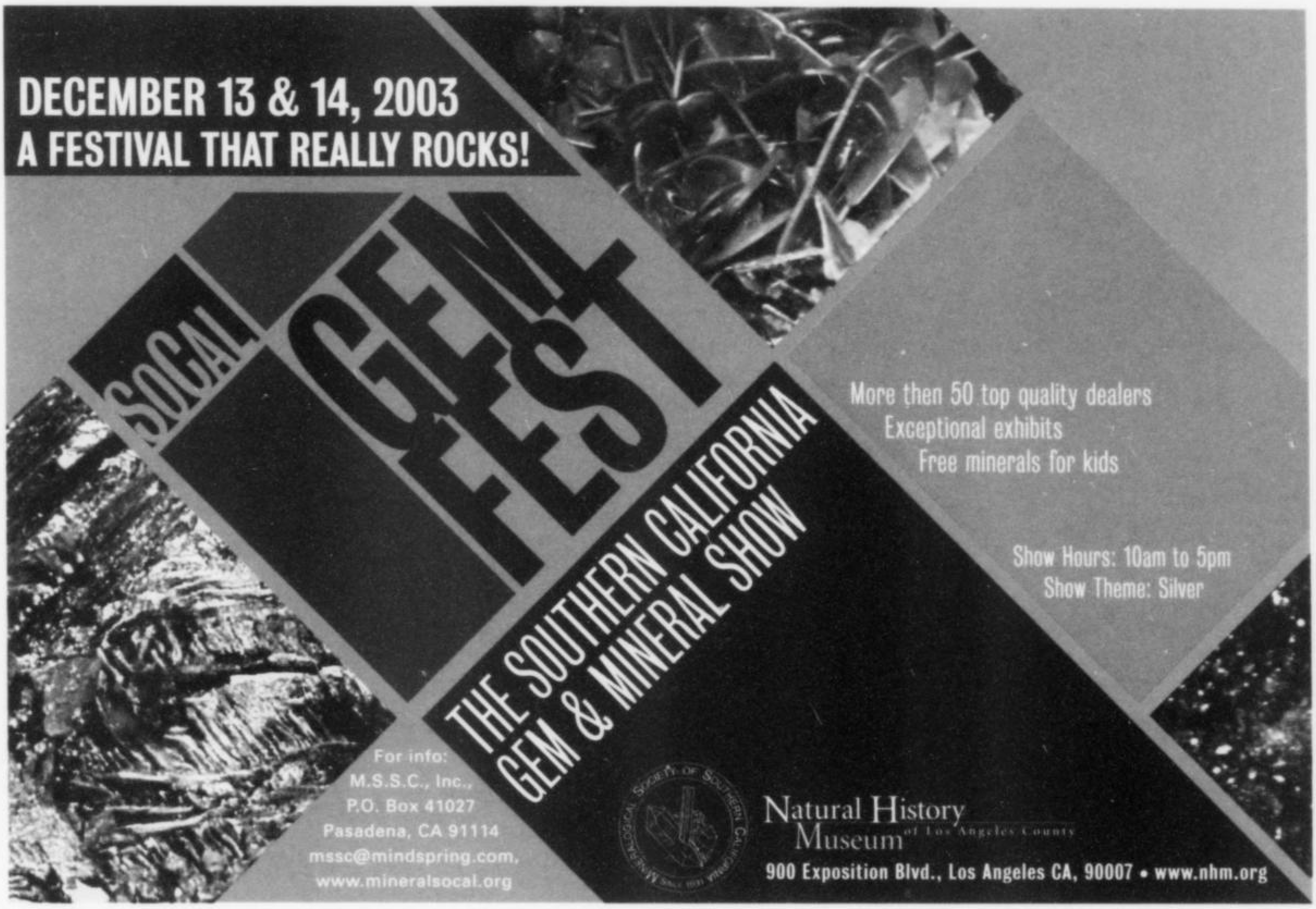

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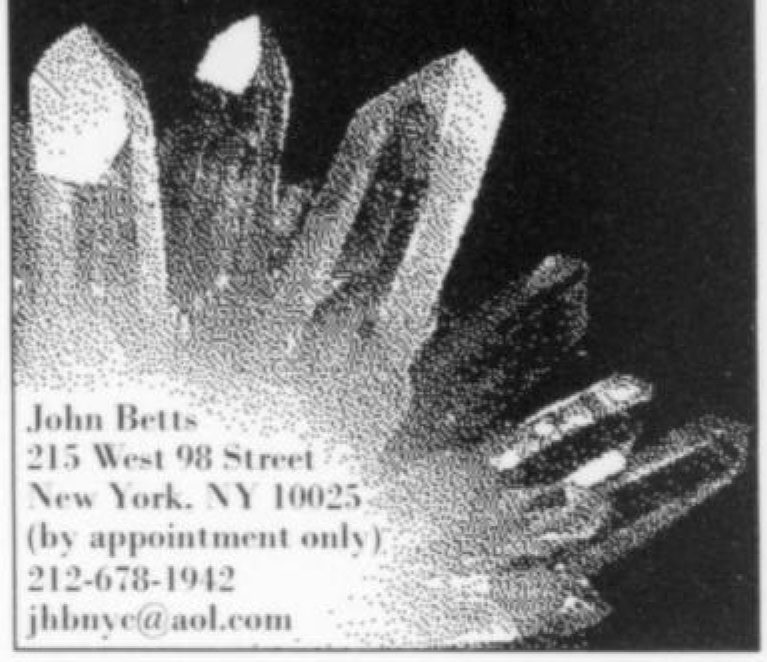

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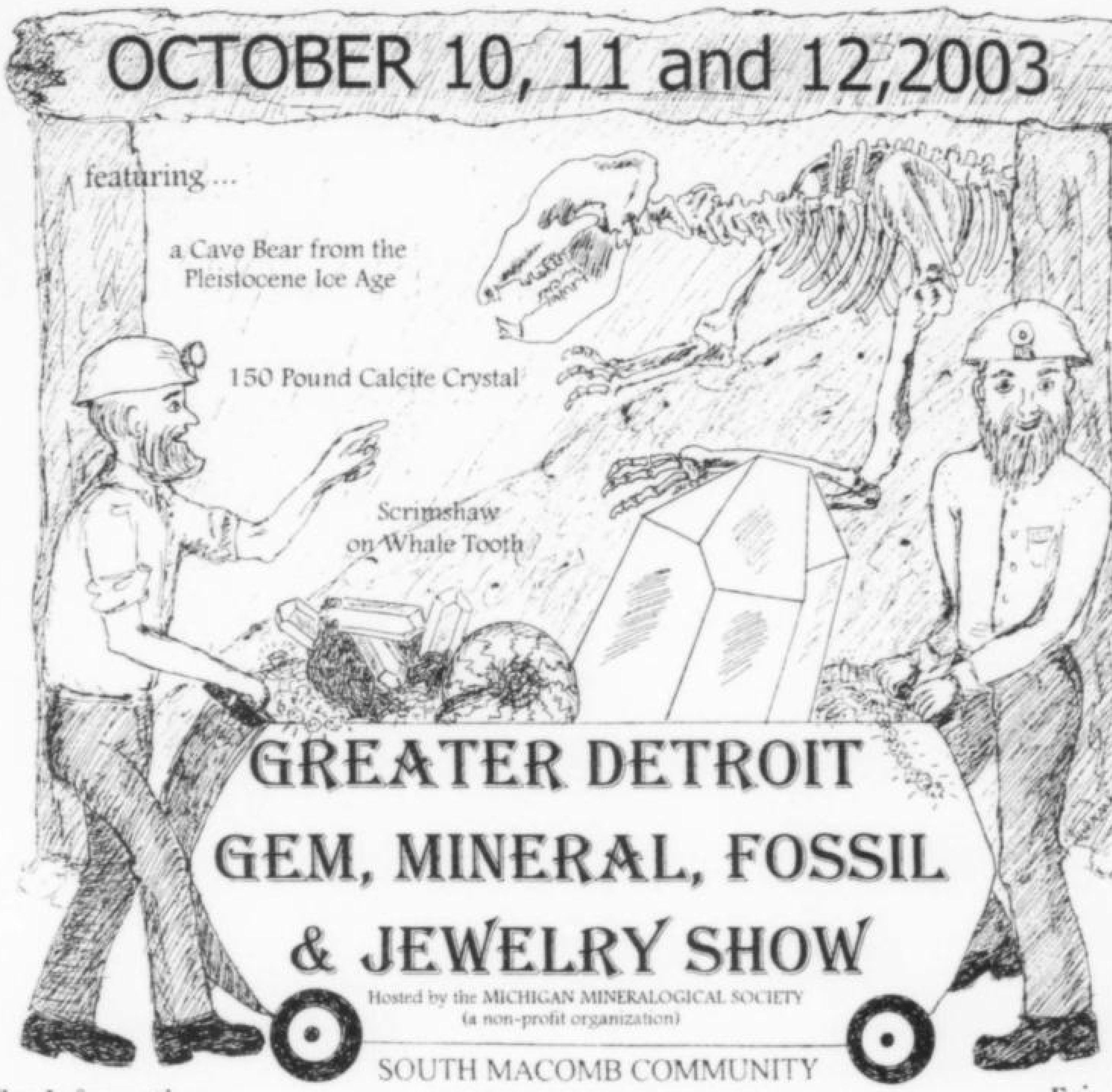

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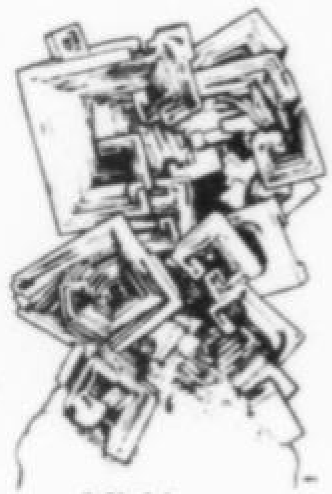

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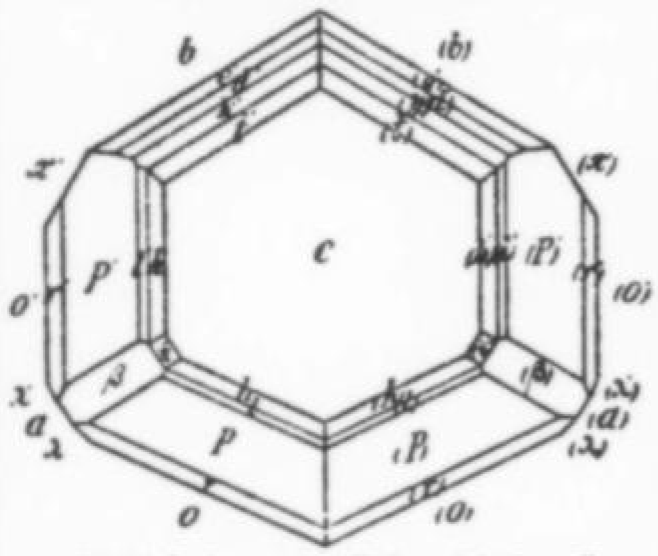

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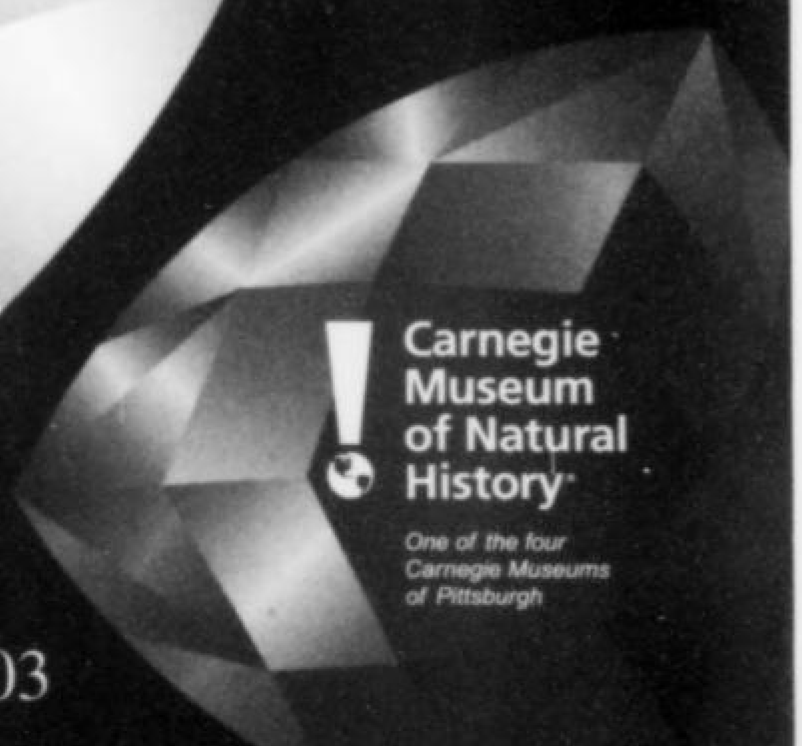

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Vol 1, No 1, Mineralogical Record, Spring 1970

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- Compiling and publishing information on mineral localities, and important mineral collections.
- Encouraging improved educational use of mineral specimens, collections, and localities.
- Support a semi-professional journal of high excellence and interest designed to appeal to mineral amateurs and professionals, through which *FM* activities may be circulated.
- Operating informally in behalf of minerals, mineral collecting, and descriptive mineralogy, with voluntary support by members.

The Mineralogical Record has agreed to an affiliation with the Friends of Mineralogy whereby it will publish its written material and news of its activities. The *Friends of Mineralogy* will support the *Mineralogical Record*, since the aims of both are similarly educational and directed toward better coordination of the interest and efforts of amateurs and professionals.

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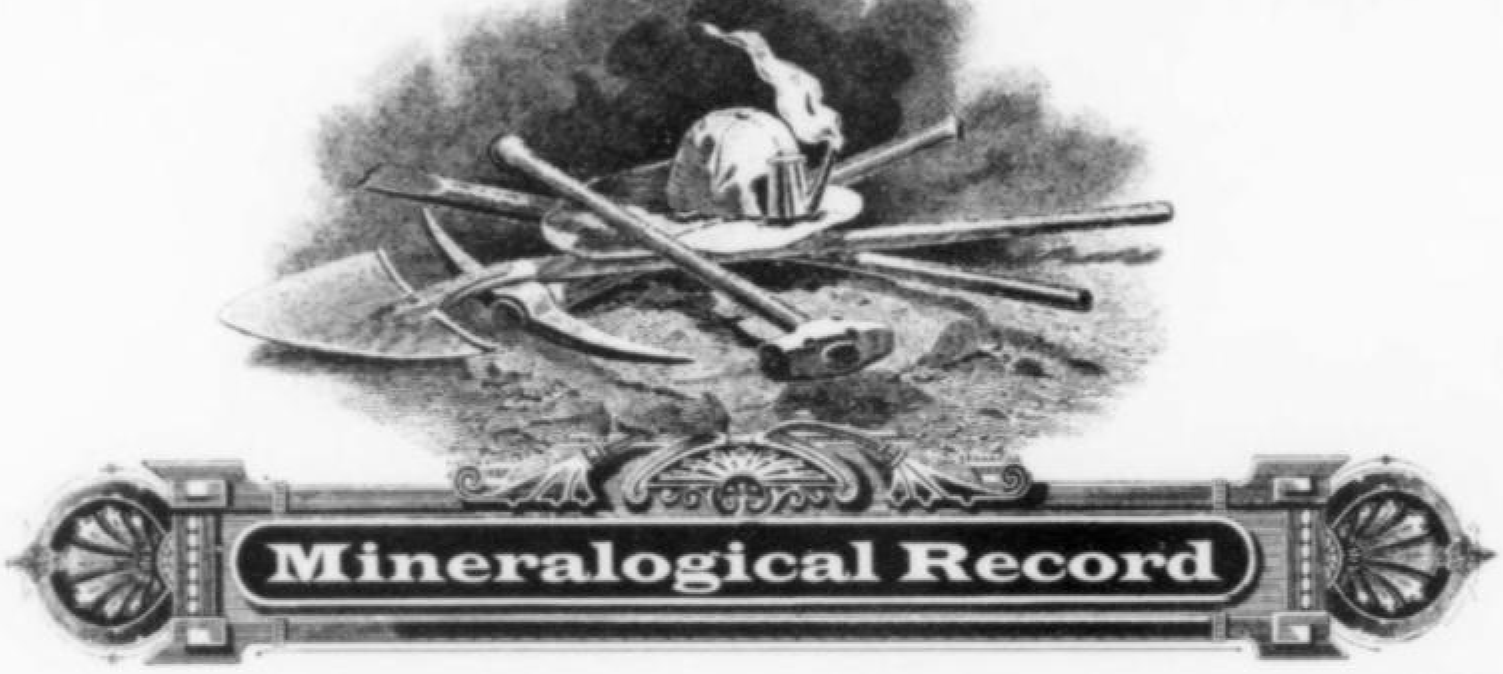

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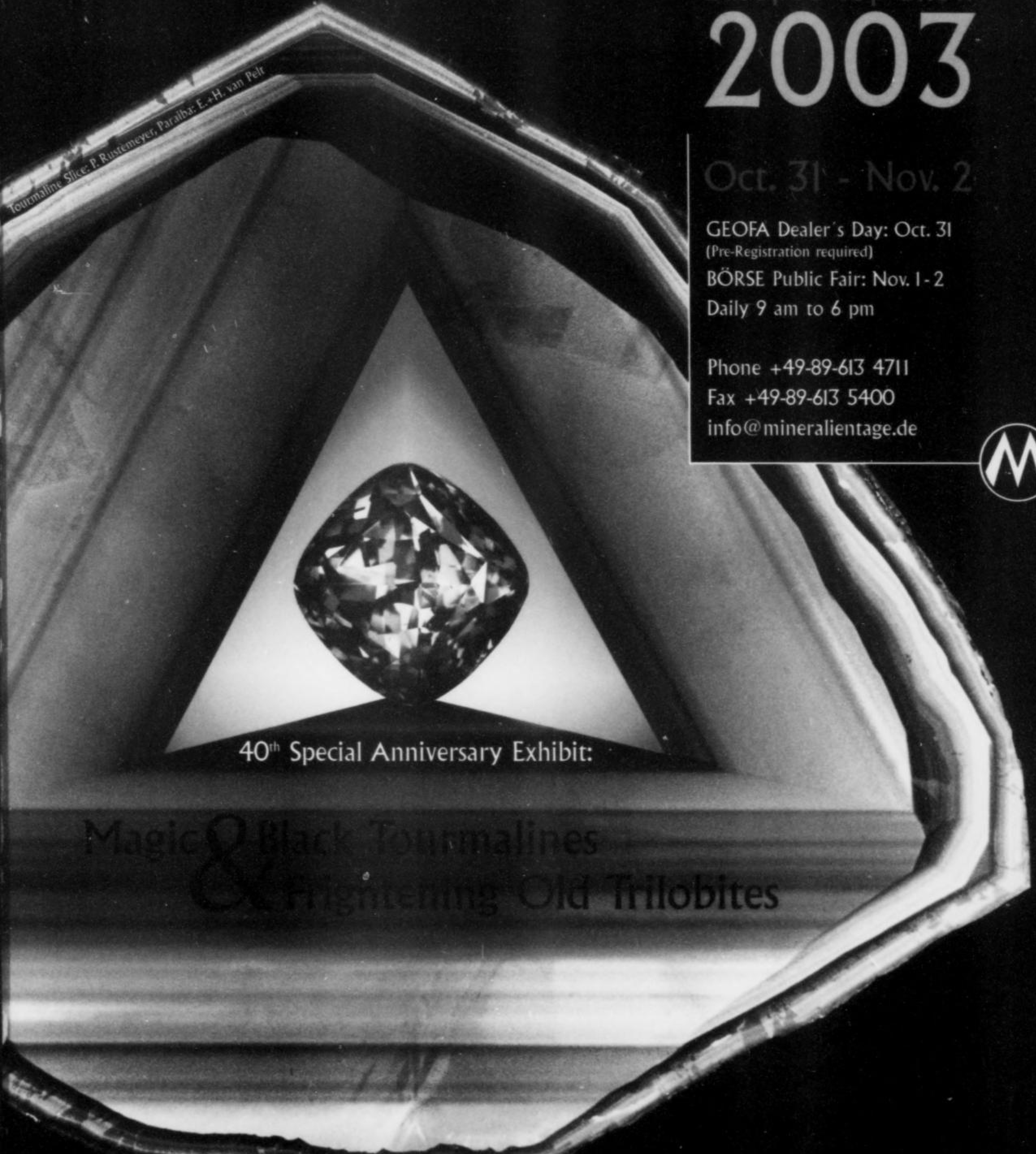

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