Mexico

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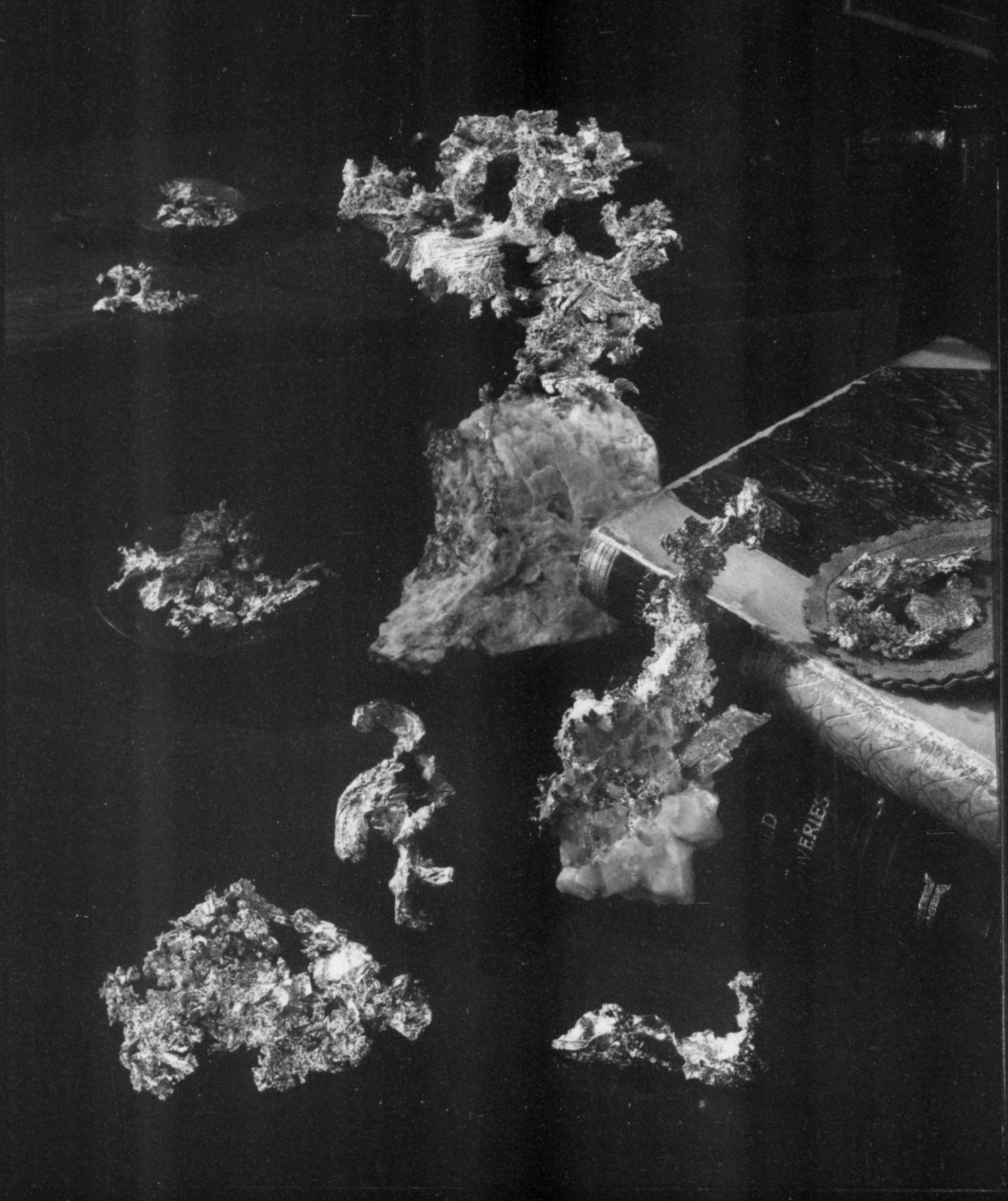

Mexico

Special Issue V

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Front Cover:
Polybasite crystal cluster in a rosette shape, with chalcopyrite, 3 cm, from the Las Chispas mine, Arizpe, Sonora, Mexico. Terry Wallace collection; Wendell Wilson photo.

Frontispiece (page 4):
"Mexican Indians working in a silver mine in San Pedro," from *The World Cities and Peoples* (1887), Cassell and Company, New York.

Mexico-V

Welcome to our fifth special issue on the mines and minerals of Old Mexico. As readers may recall, our first Mexico Issue was published in January–February 1998, the second in September–October 2003, the third in November–December 2003, and the fourth in November–December 2004. In this issue we start out with Tom Moore's evocative review of the early history of silver mining in Spanish America, illustrated entirely with artworks from the period (except for the map at the end). A part of that history is the famous Cerro Rico de Potosí in Bolivia, dealt with in detail in our January–February 1999 issue.

The Milpillas mine is the biggest surprise in Mexican mineralogy—a newly discovered deposit that in just a couple of years has yielded azurite and malachite specimens of such radiant quality as to rank it with Bisbee, Toussit and Tsumeb as one of the world's great occurrences of those species. Authors Tom Moore and Marcus Origlieri toured the working mine and gathered much new information.

What if you heard about an old Mexican mine called "The Crystals mine"? Would that be worth checking out? That, in fact, is the translation of the "Las Chispas" mine name, and it is well-named indeed. Crystal-filled cavities were frequently encountered and, thanks to the presence there in the early 20th century of an American mine manager and graduate of the Columbia School of Mines, many superb specimens were saved. Terry Wallace's article shows why this relatively obscure mine is today regarded as the source of some of the finest silver mineral specimens in the world.

And what better seasoning could there be for a Mexico issue than a dash of vanadinite and wulfenite? The Apex mine, also known as the San Carlos mine, produced many fine vanadinite specimens that still circulate on the specimen market, as well as a handful of extremely fine, red-orange wulfenite crystals.

This issue also contains a first for us: an article devoted entirely to polished specimens. But don't worry—we have not sold our souls to the lapidary gods. The items are dealt with strictly as mineral specimens, not as examples of the lapidary or jewelry arts. Right alongside the polished slabs of liddicoatite tourmaline and variscite nodules, the gorgeous agates from the classic deposits of northern Mexico have an honorable place in many fine mineral collections. Author Brad Cross is an expert on this topic, and his article is illustrated with a stunning selection of examples. And you know the great thing about photographing a cut and polished agate? The great thing is you don't have to! Just put it face-down on a scanner and scan it at whatever resolution you choose. Even large-format photography cannot capture the beauty in such pristine detail.

Once again we must thank our regular donor, Philip Rust, for the funds to present this special issue in color. He is one of the three greatest benefactors (and the only still-living one) in the history of the magazine. We all owe him a debt of thanks that can never be repaid.

Accompanying this special issue, appropriately, is a special supplement on the late Miguel Romero and his world-class collection of Mexican minerals. The display portion of that collection, part of which was on exhibit at the University of Arizona for the past 11 years, has now been sold to a foreign collector, but Rob Lavinsky, who handled the sale, has generously contributed the funds to commemorate Miguel and his collection for the sake of the historical record. Miguel was one of the real gentlemen in the mineral world, and is still greatly missed; this supplement gives us all something to remember him by.

As with the previous Mexico issues, we have had 300 copies of Mexico-V **hardbound in bonded leather**; these copies include not just Mexico-V but *also* the Romero Supplement, so they make fine collector's items and beautiful gifts. Some day, after we have finished the Mexico series, a complete set of the hardbound Mexico issues will be a prized possession for any collector to own. You can order your copy, while they last, from the Bookstore section of our website, www.MineralogicalRecord.com.

And now, as with each previous Mexico issue, it is time once again for you to sit back in that big cushy leather chair with the steer horns mounted on top, put your silver-studded boots up on the mesquite coffee table (remove your spurs first, please), call for your favorite *señorita* (or *señora* or *hombre*) to bring you a chilled margarita, and settle in for a good read.

MEXICAN INDIANS WORKING IN A SILVER MINE AT SAN PEDRO.

A Brief History of Early

Silver Mining in Spanish America

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For three centuries, Imperial Spain mined enormous quantities of metallic ore from its American domains, particularly from the huge silver deposits of Mexico and Peru. Spanish silver mining remade the economy of the Old World and did much to create that of the New; it furthered a healthy growth in mining technology, and its infrastructure proved vital to the Latin American nations after they won independence. Despite its dark aspects, the Spanish enterprise helped make the modern world possible, and many of the great silver mines developed during colonial times are familiar to mineral collectors today.

INTRODUCTION: BEFORE 1520

Shortly before the time of Christ, Iberian Spain became one of the first major foreign conquests of the expanding Roman Republic. For the next five centuries, from mining sites now largely lost, Spain furnished silver to finance and further aggrandize the great Empire which ruled it—and a thousand years after Rome's fall, history began in a peculiar way to repeat itself. Having expelled the last of the Moors, a newly unified Spain embarked on a career of overseas conquest which yielded such wealth in metals—most of all in silver—as to revolutionize the world economy, world trade, and world politics. The growth of mining, particularly in the Mexican and Peruvian parts of the Spanish New World Empire, took not only Spain but all of Europe out of itself, and did much to create that New World Order that we call modernity.

Pre-Columbian peoples of the Americas did apparently do some metal-gathering; the first treasures sent home by the conquistadores were artifacts of gold, silver and other metals wrought by craftsmen of the Aztec, Inca and other indigenous civilizations. There was rudimentary copper mining in Chile before the Spaniards, and the Incas possessed sufficient metallurgical knowledge to make some bronze. The Aztecs had plundered metal from victims of their own conquests, and the Huancavelica cinnabar deposit in Peru (later a linchpin of the Spanish mining system) had been worked by the Incas for cosmetic "rouge" (Waszkis, 1993). But mining in

Figure 1. (above) **An 8-reales coin dated 1727, minted from silver mined at Cerro Rico de Potosí, Bolivia. Because it is very round instead of being struck on a crude, free-form planchet it is known as a "royal" strike; this coin sold at auction in 2008 for over $120,000.**

Figure 2. **It all started with the Spanish King Ferdinand V and his wife Isabella. Their sponsorship of Columbus's expedition to the New World launched one of the most expansive searches for precious metals in history. The extremely rare gold coin pictured here, shown actual size, was minted some time between 1497 and 1504; it is a 50 *excelentes* piece, and bears their portraits.**

pre-conquest times was probably largely confined to sluicing for alluvial gold, and some hacking at outcrops of metalliferous veins, followed by very primitive sorts of smelting; no seriously developed underground workings seem to survive from before 1500 in the Americas (Waszkis,, 1993).

The early 16th-century Spanish campaign of conquest in the New World was one of the most brilliant, brave and merciless such adventures in all of history. It flowed from a complex set of historical circumstances and mixed motives: narrow horizons at home, military momentum from the campaigns against the Moors, religious zealotry, and sheer Renaissance-age adventurousness. But the one force which permeated and motivated all the others seems to have been the greed for gold and treasure. When the Aztec Emperor Montezuma offered gold to Cortez in an effort to persuade the Spaniards to leave Mexico (one of history's more ironic miscalculations), Cortez is said to have answered "Let him send the gold to me, for I and my companions have a complaint, a disease of the heart, for which gold is a certain cure" (Rickard, 1932). The first march on the Aztec capital, the seizure of the Aztec treasure, and the murder of Montezuma all followed directly.

The well-known Spanish excesses of plunder in this early period have led to the habit of stereotyping the whole 300-year history of Spanish rule in the New World as a nightmare of exploitation, misrule and static backwardness. Of course, the record is more mixed than that. Apologists for the Spaniards point out that in general they were conscientious about "civilizing" their empire (granted that civilizing mostly meant Europeanizing and Christianizing), and that the quest for mineral wealth led finally to the construction of physical, economic and social structures which worked quite well for the Latin American nations following independence. And one writer wryly observes that "the strongest criticism of the eager and tireless pursuit of gold and silver deposits in America [has] come precisely from those nations that organized piratical enterprises to seize the bullion and coin as booty on the high seas" (Prieto, 1973). This essay cannot, of course, attempt revisionist judgments on the abundance of historical facts that have come down to us about the Spanish adventures in the New World. Some of the conquistadores themselves, such as Cortes, were well educated and kept good records; even the functionally illiterate Pizarro kept good scribes with him; and missionaries, mendicant friars, and amateur naturalists who followed closely after the conquest amply recorded what they saw (for a survey of early sources see Lafaye, 1984).

Some of the early legends and wish-fantasies of New World wealth that inspired the Spaniards have remained well known. The story of *El Dorado*, "the gilded man," was first reported in 1636 by Juan Rodrigues Freyle; he described a ritual in which a chief or priest of the Muisca tribe in New Granada (now Colombia) would cover himself in gold dust, take a boat into the middle of a lake, and toss out treasure as a tribute to the local god. This legend may well be true, as numerous gold artifacts have been recovered from the likely site, Lake Guatavita. Rumors of "El Dorado" subsequently morphed into a city or land or tribe of that name and seduced some of Pizarro's men into the interior of South America. (Voltaire used the motif of El Dorado in his 1759 novel *Candide*, making the El Doradans a rather dull, incurious people, bored by their own perfection). Coronado's party was moved to push farther and farther north from New Spain (Mexico) into what is now the southwestern United States, because the mythical golden Cities of Cibola always lay, locals told them, just a little farther ahead. The Guarani Indians of Paraguay told the Spaniards of a great "mountain of silver" somewhere inland, and of a fabulous imperial city awash in wealth. Reality, naturally, proved less exciting: Cibola turned out to be some poor adobe villages of the Zunis; and the Andean "City of the Caesars," was actually the Inca capital of Machu Picchu. The mountain of silver in fact did exist, and would be discovered in 1545: it was Potosí mountain in what was then Peru (now Bolivia), one day to become the world's richest silver mine. Dreams may deign to come true, if seldom with a full complement of special effects.

The first territories seized by the Spaniards were the Caribbean islands, explored and partially settled and colonized by Columbus (who believed to his death that this was an archipelago lying just off the coast of Japan). The friendly Taino Indians of Hispaniola had some gold, which they panned from streams in the hills; the Taino were promptly enslaved by the Spaniards for the purpose of finding more gold, and within 50 years they had virtually been driven to extinction, mostly by European diseases, partly by overwork and mistreatment. Though small quantities of alluvial gold from various West Indian islands were sent to Spain for decades, these earliest conquered lands proved disappointing for mineral wealth, though satisfactory as bases for further colonial operations. The alluvial gold mines in Colombia and Venezuela later did prove highly profitable (see Wallace and Hall-Wallace, 2003, for a brief account); these deposits came to be worked primarily by African slaves, who were thought better suited than native American slaves for hard work in tropical lowland regions. However, no more will be said here about gold mining in the Viceroyalty of New Granada (modern Colombia and Venezuela), or about the gold exploited somewhat later in Chile, or about gold and diamonds in Portuguese Brazil, or even about emeralds in Colombia. Although extensive, most of these enterprises did not involve hardrock mining, and did not have economic and cultural consequences anything like what was destined to follow from the discovery of the great silver deposits of Mexico and Peru during the first two or three generations after Columbus.

MINING BEGINS IN MEXICO

The story of the conquest of Aztec Mexico by about 600 horsemen under Hernando Cortez is a familiar one to most North Americans—beginning with the idealized version in old-fashioned

Figure 3. **Montezuma, the ruler of Mexico-Tenochtitlan, is said to have observed a blazing comet—an omen of death—one night from the top of an observatory. The Spanish Conquest followed, and in retrospect the sighting of the comet was regarded as a premonition of the invasion. Contemporary painting from the *Codex Durán,* Chapter LXIII.**

secondary-school textbooks. A central image in the picture/story is always the "treasure of Montezuma": a roomful of gold and silver bullion and worked artifacts, long accumulated by the emperor's forefathers, taken as booty by the Spaniards. Some of this loot was allotted to individual soldiers, some was lost along the marches, some was captured at sea by French and British pirates, and some (melted into crude bars for easier transport) actually reached the Court of Spain. Nor did the plundering phase of the conquest end here: the Spaniards learned that the Aztecs had buried their high-born in graves full of treasures, and so a search for the tombs of Aztec nobles was conducted, and tons of gold objects were disinterred and melted to bullion (Rickard, 1932). But the Spaniards were not long content just to take metal mined by others and already worked; very soon they were off to discover and mine deposits themselves.

The very first Spanish silver mines in Mexico were some small ones at Morcillo in Jalisco, and near Compostela in Nayarit; these were begun in about 1525, but were soon abandoned (Prieto, 1973). Another mine dating from sometime in the 1520s, the Michoacán mine west of Mexico City, collapsed in an earthquake just after work had begun (Diffie, 1945). Around 1530, workings were opened in Zacualtipán and Sultepec, in the present state of Mexico, and at Zumpango in Guerrero (Prieto, 1973; Bakewell, 1984). Then, in 1534, came the first workings in a truly major lode, one whose name is still familiar to mineral collectors: Taxco, in Guerrero. At Tehuilotepec, near the new town of Taxco, the first true mine adit opened by Spaniards in the New World, the so-called Cortez tunnel, was dug by members of the original Cortez expedition; it eventually reached 90 meters long, and was large enough to be entered by a man on horseback. Besides silver, Cortez mined tin and copper at Taxco, using the metals to make bronze for cannon (Prieto, 1973).

In 1546, Juan de Tolosa, one of Cortez's lieutenants, discovered the great silver deposits of Zacatecas, reportedly finding the outcrop at the foot of the Cerro de la Bufa near the site of the present-day city of Zacatecas. In 1548 the first mine in the Veta Grande ("Great Vein") system near Zacatecas was opened: called the Alvarado mine, it too was worked by Cortez, who kept extensive and accurate records (C. B. Dahlgren saw these in the Mexican state archives sometime before 1883, and commented ". . . they are very curious old documents, and are illustrative of the exactness with which all the accounts of the old Spaniards were kept in those times").

The northward rush was on: around 1548, Guanajuato was discovered; around 1552, Pachuca; around 1553, Fresnillo; around 1558, Sombrerete. In either 1547 or 1567 (sources differ) came the discovery of the Santa Barbara orebody, the first deposit to be found in the present state of Chihuahua; in 1592 the San Luis Potosí deposit, and in 1598 the Ojuela deposit at Mapimí, Durango, were discovered. In fact, evidence of Spanish workings has been found in virtually every silver deposit discovered later in what is now the southwestern quarter of the United States. In 1552 a long-rumored Mexican "mountain of silver" was found instead to be a mountain of iron: this was the Cerro de Mercado deposit in Durango, much later to be of major importance to the Mexican iron and steel industry, but doubtless disappointing to its discoverer, Ginés Vázquez Mercado (Prieto, 1973).

Many of these deposits had been scratched at by earlier peoples, but the true mines were Spanish creations from the beginning. Before their exploitation there had been almost no trade, town life, or even agriculture along the routes between Tenochtitlán (the Aztec predecessor to Mexico City) and the northern regions. But with the headlong Spanish expansion, driven by the lust for silver, towns sprang up, and with them crop-farming, and the raising of livestock, and viticulture, and all kinds of commerce and trade, and the march of the Church. Especially to the north, in the wild areas beyond the pale of the ancient Aztecs, there is hardly a modern Mexican town that did not begin as a mining boom town; San Luis Potosí, Parral, Nuevo Leon, Monterrey, and hundreds of others were originally sites fortified by the Spaniards to guard metal deposits (Jenison, 1923).

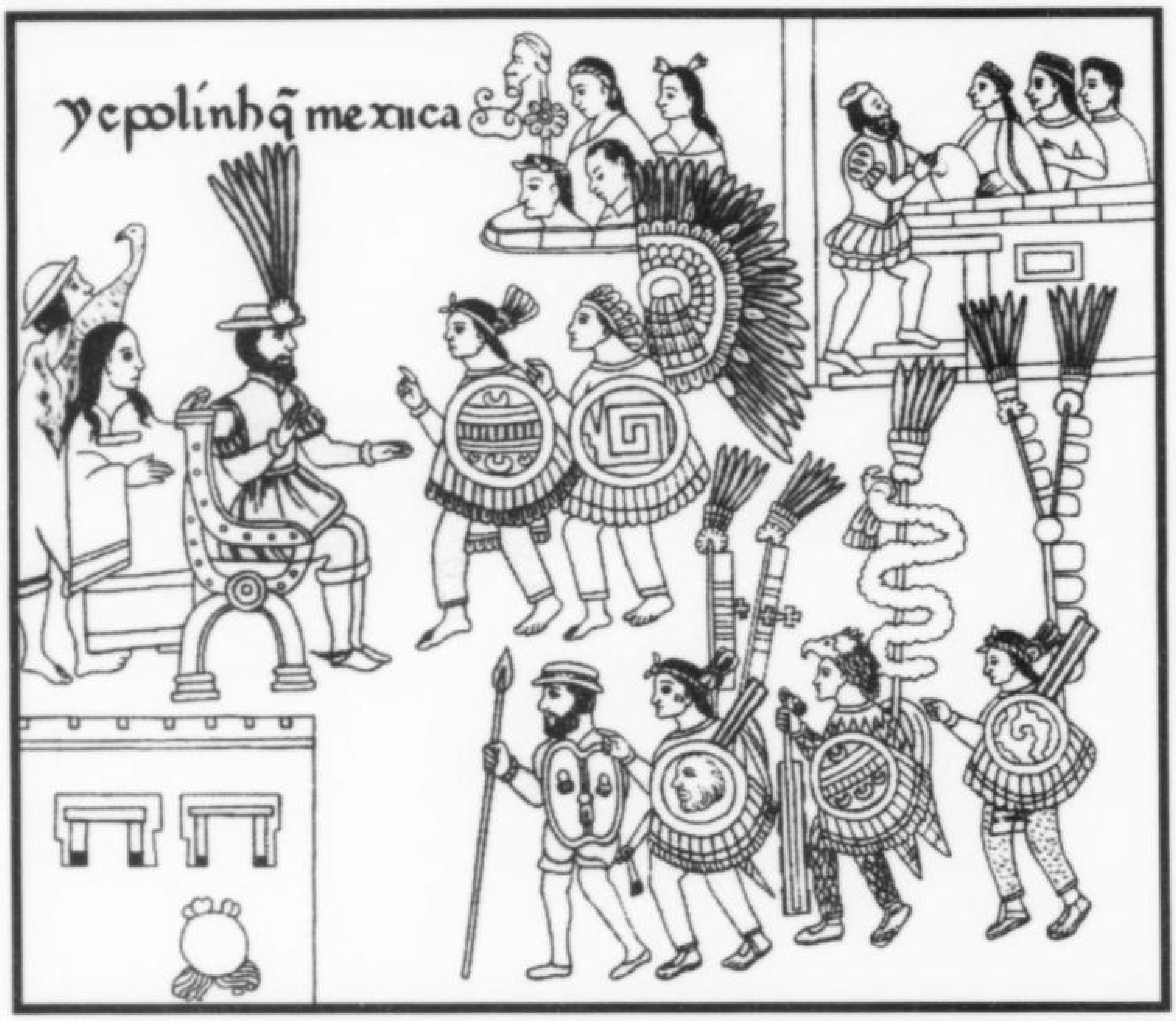


Figure 4. **Cortez accepts the surrender of the Aztec chief Cuahtemoc. Contemporary Mexican painting from *Lienzo de Tlaxcala*; the German Library, Marburg.**

Figure 5. **The only known contemporary European painting depicting conquistadors. Three Germans (Georg Hohermuth, Nicolaus Federmann and Andreas Gundelfiner) are off to join a Spanish expedition in 1534.**

The town of Durango was founded, a typical legend has it, by one Captain Ibarra, who in about 1575 took possession of an open-cut mine called the Avino (still active today), and offered to deed it to any men who would build their houses together around the mine to protect it against wild Indian forays (Southworth, 1905).

Meanwhile, in Mexico City, the Spaniards were sinking roots. In 1550, an inclusive mining code was issued by Viceroy Antonio de Mendoza, and in 1551 the University of Mexico was founded. Not two generations after the first campaigns of Cortez, a culture had sprung from the seedling of the conquistador quest for silver and gold, and the output of the new mines had already entirely dwarfed the ready-made treasures for which Montezuma was murdered.

Figure 6. **The original "El Dorado" or "Golden Man" was a local chief in Colombia who routinely had himself oiled and covered in gold dust. Legends of El Dorado inspired generations of conquistadors searching for gold and silver throughout the 16th and 17th centuries (engraving by De Brye, 1590).**

MINING BEGINS IN PERU

Vasco Nuñez de Balboa is chiefly remembered today for bringing Panama into the Spanish realm, and for being the first European to gaze out upon the Pacific Ocean—"with a wild surmise/Silent, upon a peak in Darien," in Keats' lines, "Darien" being the term for the Isthmus of Panama. One day, when some Spaniards were quarreling over the division of some gold they had just robbed from a native tribe, a chief of the tribe stepped forward (goes the story) and said "Why quarrel over so little? If it is gold you want, I can tell you of a country where there is so much that even the commonest things are made of it." This Eldorado, he told Balboa, was distant six suns (days) to the south, over the mountains and on another sea . . . and this was the Spaniards' first hint of Peru (Rickard, 1932).

Balboa himself never saw the land of the Incas; it was one of his captains, Francisco Pizarro, who arrived at its borders in 1532 with about 200 mounted soldiers. Fortunately for the newcomers, Inca Peru was involved in a dynastic and civil war at the time—for a sketch of the politics of the conquest see Crowley, Currier and Szenics (1997: the "Peru Issue"), and Wallace and Hall-Wallace (2003). As in Mexico, there was a betrayal and assassination of a king for his treasure: this was the Inca king Atahualpa, who, when captured by Pizarro, offered to ransom himself with a room full of gold and two rooms full of silver. Legend has, of course, inflated the treasure's dimensions; Bain and Read (1934) suggest that it was about 230,000 ounces of gold and silver vessels and ingots. There were to be further conflicts, both between Spanish and Incas and within each of these groups, but in general the conquest of Peru was easy. The Inca empire had been falling apart in any case, and the Incas' former subject peoples probably did not much mind when the Spaniards made slaves indiscriminately of Incas and lesser indigenous folk.

The first silver mines to be exploited by the Spaniards in the vast Peruvian province were in its southern part: the region called "Charcas" which is present-day Bolivia. The Porco mine, southeast of Potosí, had already been worked in a small way by the Incas. Its ore was chiefly pyrargyrite, called "rosicler" by the Spaniards. Beginning in about 1549, Pizarro himself directed work at the Porco mine and, a contemporary wrote, "received annually from the pure metal that was extracted more than 200,000 gold pesos" (Prieto, 1973). Such sums nicely supplemented what the Spaniards were earning from finding gold in the mountain streams and from plundering Inca treasure (the plundering included a grave-robbing campaign even more massive than the one in Mexico).

The mountain of silver at Cerro Rico de Potosí was discovered in 1545. Perhaps the term "rediscovered" is better, since an Inca chieftain, Hualna Capac, is reported to have seen Potosí mountain in 1462 and to have intuited from its beauty that wealth lay within. An Inca mining expedition (so the story goes) was frightened away by a mysterious thunderous noise from the peak, the name "Potosí" being derived from the Quechuan word "potocsí," meaning "place of great noise" (Wallace and Hall-Wallace, 2003). There are, in addition, at least three competing legends about the Spanish discovery of this, the greatest silver deposit ever found anywhere in the world to that time. The three stories all involve an Indian named Gualca

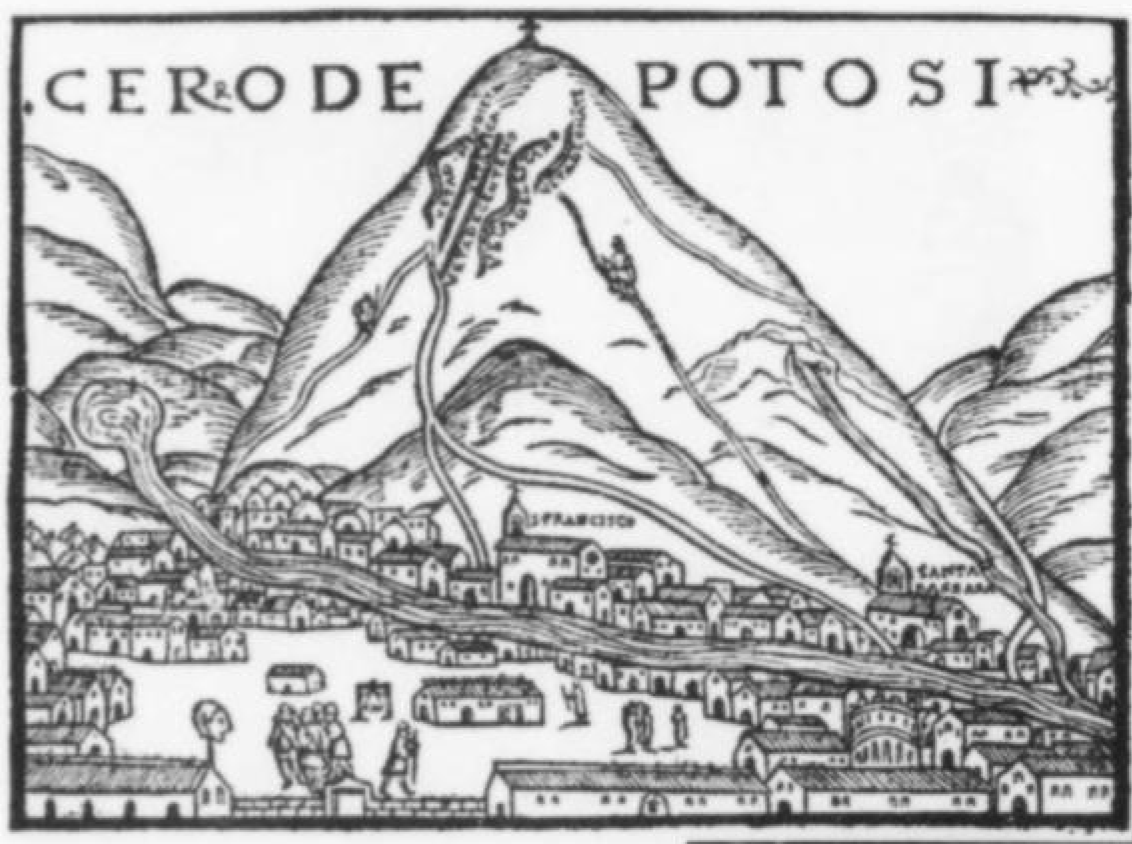


Figure 7. **A woodcut illustration of Cerro Rico de Potosí from Pedro de Cieza de Leon's *Cronica del Perou* (1556).**

Figure 8. The image of Potosí Mountain became iconic in Bolivia for centuries, depicted even on coins. The example shown here is an 1835 8-escudo gold coin (Norweb sale, MS-61; Wendell Wilson collection and photo).

Figure 9. **Oil painting of Potosí, Mountain—"The Virgin of the Mountain," painted by an unknown artist around 1765. Museo Nacional de Arte, La Paz, Bolivia.**

and a llama. In one version, Gualca had camped for a night on the mountain and tied his llama to a bush, awakening the next morning to find that the llama in its vigorous grazing had exposed a vein of silver. Or then, perhaps, Gualca had been tracking the llama, which had strayed away up the mountain, and he had stopped at dusk to build a campfire, and found, the next morning, that the fire had released little streams of pure silver from the rock. But some say that Gualca had been climbing a steep slope in search of the strayed llama and, seizing a queñua bush to cling to, uprooted it, exposing a silver vein in the hillside (Rickard, 1932). In any event, Gualca told his master, a Spaniard named Villaroel, about the vein,

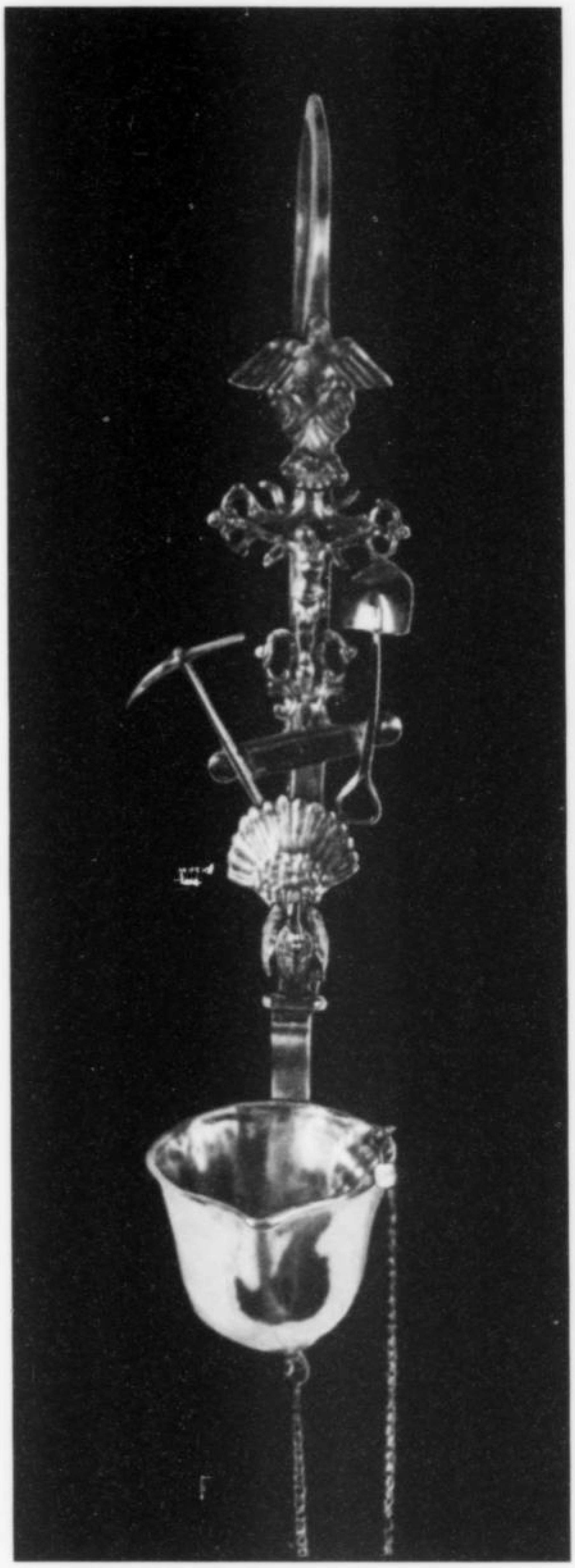


Figure 10. **A solid silver miner's oil lamp (probably a presentation piece), 41 cm tall, decorated with representations of mining tools; made in Potosí, Bolivia in the mid-1700s. Collection of Carlos and María Iturralde.**

and Villaroel registered the claim in his own name and Gualca's on April 21, 1545, at Porco.

Between 1545, the year of discovery, and about 1600, the mines of Bolivia produced half of all the world's silver (Bain and Read, 1934), most of it from mines on Potosí Mountain. A traveling friar, Josef de Acosta, wrote a mouth-watering description of the ore visible on the "mountain of silver" in those days: "The metal was an outthrust in the form of crags . . . like a crest three hundred feet long and thirteen wide . . . [and its] color is a sort of dark red" (quoted in Prieto, 1973). Was this ore pyrargyrite, as at nearby Porco? It would be nice to think so, but it was instead probably iron-stained native silver and chlorargyrite (Wallace and Hall-Wallace, 2003). In any case the mountain was soon honeycombed with mine workings, and Acosta would later estimate that $250,000,000 in silver came from it between 1545 and 1572 (Wilson and Petrov, 1999). By 1570 the town of Potosí had attained a population of 120,000, and had become the largest city in the western hemisphere, a distinction it maintained for some years into the 1660's (Currier, 1995). On its windy height at the edge of the world, at an elevation higher than that of Lhasa, Tibet, the city enjoyed a cosmopolitan life such that every day there would arrive "silks and carpets from Africa; perfumes from Arabia; diamonds from Ceylon; crystal, ivory, and precious stones from East India," etc. (Prieto, 1973). The miners gambled lavishly on jai alai games (the Viceroy Toledo disapproved, since the games brought together crowds of idlers and took time from mining), shopped for luxury foods in the enormous market, and bought themselves sumptuous funerals; the local generals and dons spent millions of pesos to dower their daughters for marriage. Today Potosí is a desolate, largely worked-out place (Currier, 1995; Wilson and Petrov, 1999), having already begun to decline by the early 17th century, but at its peak—within 50 years of Pizarro's initial conquest—it was splendid, "The Envy of Kings" as the city's motto proudly proclaimed.

A second spectacular find made in early times in the Viceroyalty of Peru was Cerro de Pasco, in the modern state of Peru, discovered in 1630. Now an open-pit mine producing chiefly copper (Currier, Crowley and Szenics, 1997), Cerro de Pasco was worked by the Spaniards for silver from its near-surface, oxidized ores. Up until 1870 its silver bullion, smelted on-site, was transported by llamas 200 miles to Lima (Bain and Read, 1934). Production in the early 17th century became so rich (while production at Potosí meanwhile declined) that in 1661 Peru took over from Bolivia the distinction of being the world's leading silver-producing region (Mexico being third). By the end of the 18th century, the Cerro de Pasco district was the most important in Peru; its production peaked in 1804 (Wallace and Wallace, 2003).

The Spanish discovery of the cinnabar deposit at Huancavelica, Peru around 1560 proved vital for the prosperity of silver mining in the New World because the "patio process" for the amalgamation of silver ores (invented in Pachuca by Bartholomé Medina in 1554 and used widely in the New World thereafter; see later) required mercury. It was fortunate for Spanish mining that Enrique Garcés, a Portuguese merchant and poet who arrived in Lima in 1547, noticed the red "rouge" with which Indian women painted their faces, and recognized it as the substance found in mercury deposits. Garcés proceeded carefully: he first verified that Peruvian cinnabar was indeed the same mineral as was exploited at the great mercury mine at Almadén, Spain. He investigated the patio process as it was being practiced in Mexico with mercury from Almadén, and then demonstrated the process to the Peruvian Viceroy. He was soon granted a 12-year monopoly for the cinnabar mine in Peru (Prieto, 1973). Garcés was thus the first European to work what came to be called the Santa Barbara mine, one of the greatest mercury mining camps in history and an indispensable element of the Spanish mining system: according to the Viceroy of Peru in 1648, Huancavelica was, with Potosí, one of the "two poles which support this kingdom and that of Spain" (Wallace and Hall-Wallace, 2003). The mine is estimated to have produced 55,000 tons of mercury in its lifetime, but it achieved a black reputation, even by Spanish standards in colonial times, for mismanagement, corruption and gruesome working conditions (for some particulars see Wallace and Hall-Wallace, 2003). Crippled by a collapse of its workings in 1786, the Santa Barbara mercury mine closed permanently when Spanish America won independence in the early 19th century.

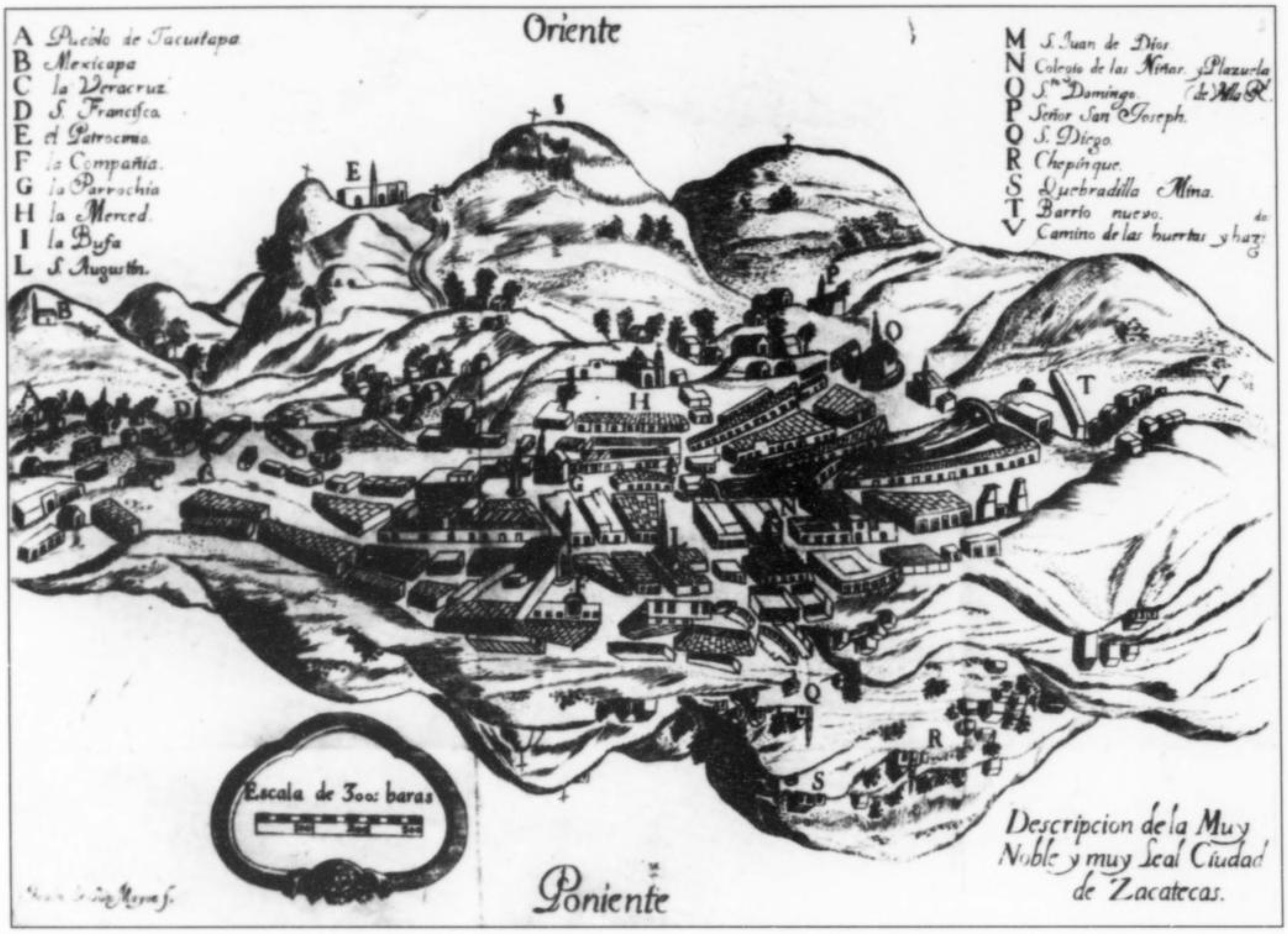


Figure 11. **A view of the rich silver-mining city of Zacatecas at the height of its prosperity. From Joaquín de Sotomayor's *Descripción breve de la muy noble y leal ciudad Zacatecas* (1732).**

RICHES FROM RAT HOLES

Contemporary accounts of the mineralogy of the silver deposits as the Spaniards found them are frustratingly few and vague—one would like to have better than awed images of "dark red" ore crags. It could well be, of course, that rich supergene veins containing great masses of silver sulfosalts cropped out on the surface, and certainly some accounts of early bonanzas suggest this. "Ruby ore" (proustite/pyrargyrite) in veins up to four feet wide is said to have cropped out commonly on the Cerro de Proaña hill at Fresnillo, discovered in 1555 by Juan de Tolosa. Such veins "gave several bonanzas, the last one in 1792" (Dahlgren, 1883). But Diffie (1945) observes soberly that, in general, American silver ores were leaner than those in European deposits, the enormous productions of silver from American mines being due to the tremendous size of the deposits. Fausto de Elhuyar, Director of Mines in Mexico near the end of the colonial period, found that a quintal (100 kilograms) of average Mexican ore yielded only 3 to 4 ounces of silver, whereas the mines of the German/Bohemian Erzgebirge averaged 10 to 15 ounces per quintal.

Probably the very richest outcroppings or near-surface deposits worked by the Spaniards consisted of highly oxidized, brownish or reddish gossans (such as the "dark red" ledges of Potosí) suffused with chlorargyrite. Potosí Mountain was well oxidized to a depth of 1,000 feet below the summit (Bakewell, 1984), and Acosta wrote that its richest ore was "of the color of amber," and easily smelted (Rickard, 1932). These chloride ores were called *pacos* in Peru and *colorados* in Mexico, while the black sulfide ore below (acanthite) was everywhere called *negrillos*. Before the advent of the patio process, these ores were simply roasted out of the veins, then reduced in crude furnaces: one observer wrote that "the Peruvians get the silver by burning the hill, and, as the sulfur stone burns, the silver falls in lumps" (Rickard, 1932). Quechan silver-ore smelting techniques were the most advanced in the New World in pre-Spanish times (Wallace and Hall-Wallace, 2003), but it is not always clear whether descriptions like the one cited above refer to ancient Indian practices, performed by Indian slaves under Spanish supervision, or to the Spaniards' own improvisations.

The earliest underground mining techniques were also primitive, designed to exploit very rich, shallow ores for quick profits. The initial abundance of slave labor, plus the Spaniards' own amateurism and greed, led the typical mine supervisor first to attack a deposit with a small open pit, then to burrow irregularly in pursuit of especially rich feeder veins. This approach, which produced narrow, twisting tunnels, was called in Mexico the *sistema del rato*: translated by some as the "opportunistic system," from *rato* as "rate," i.e. of time, but a pun on "rat-hole" may have been intended from the beginning. Nevertheless, the Spaniards did seek to learn and apply new technologies as required. In 1556 the first true mine adit in South America was run into Potosí Mountain to exploit the ore near the peak, and by the early 1580s there were nine adits in operation at Potosí. By the early 17th century there was large-scale mining through adits also at Potosí's namesake, San Luis Potosí, Mexico (Bakewell, 1984). In the late 16th century, pumps were in occasional use for draining mines, and animal-powered whims were becoming more common. The world's first use of underground blasting for ore occurred in Germany in 1627, but blasting had come to the Huancavelica mercury mine by 1635, and it reached Potosí soon thereafter.

Before the advent of the patio process, the Spanish in South America borrowed their ore-smelting technology from the Incas. The ore was crushed by rocking or dragging a curved boulder over it, then smelted in a conical or pyramidal furnace about three

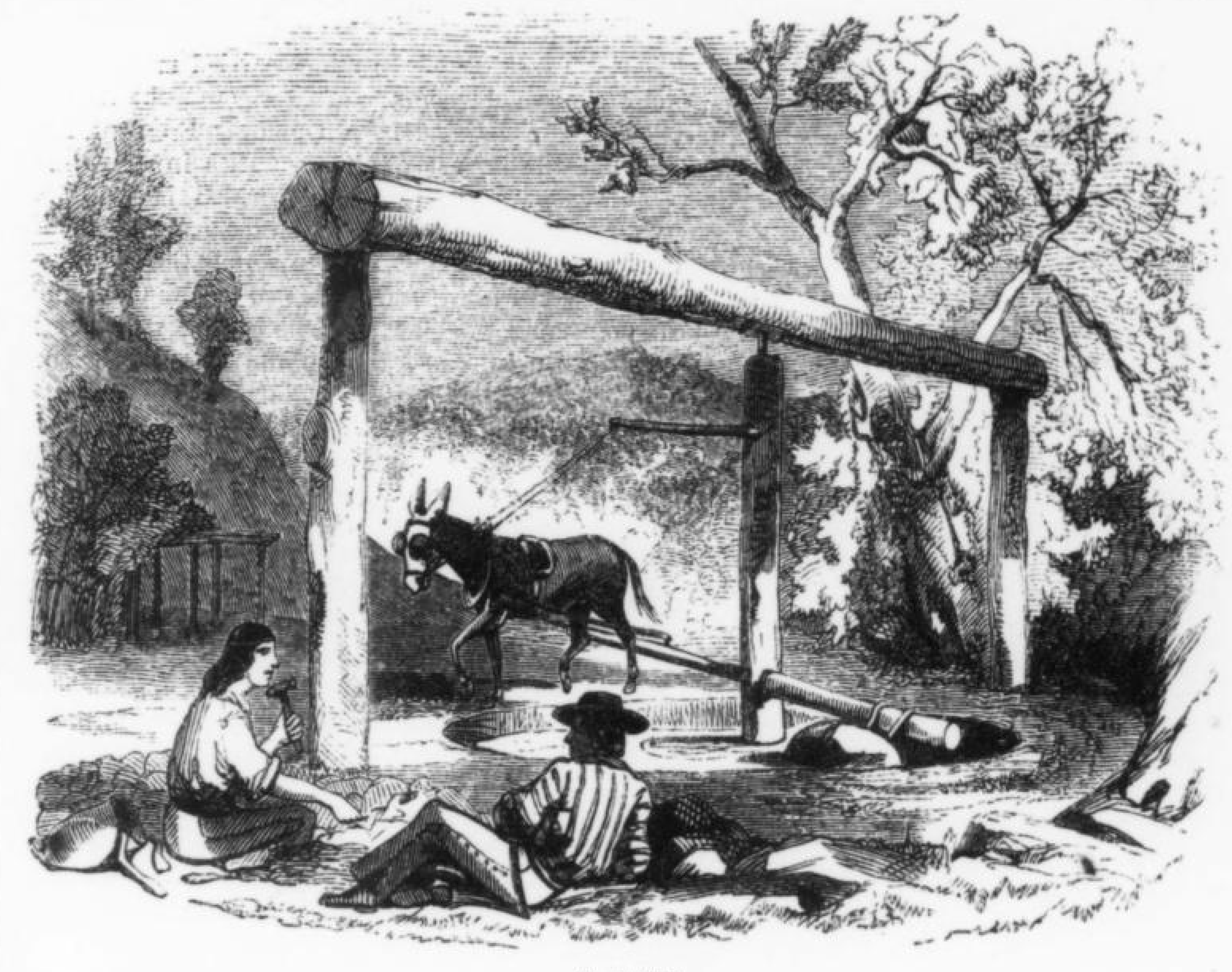


Figure 12. **An arastra, the typical method of grinding silver ore preparatory to processing by the patio method. From *Harper's New Monthly Magazine* (April, 1860).**

Figure 13. **"Miners of Spanish America in full dress," an illustration from Louis Simonin's *Life Underground, or Mines and Miners* (1869).**

feet high. The furnace, pierced by many air holes, was set in a cold, windy place, and with llama dung or charcoal as fuel, sufficiently high temperatures were obtained. This method persisted, especially in small mines worked by poor individual miners, well into the 17th century. Around 1536, however, some German mine engineers brought in by the Crown to help with mining technology in Mexico built milling machines at Sultepec, and introduced a smelting device called the Castilian furnace: a hollow vertical column about three feet across and six feet high, built of stone or adobe, with its sides pierced for bellows and for the drawing-off of slag and molten metal.

These early technologies were rendered instantly obsolete, and the whole Spanish-American mining industry took a quantum leap forward, in 1554 with the advent of the "patio process" for the amalgamation of silver ores. As already mentioned, it is Bartolomé de Medina who is generally credited with having pioneered the process. A Spaniard from Seville, Medina may have known Agricola's *De Re Metallica*, which describes a similar method, but it is clear that he worked out the patio process at the Pachuca mines, in Hidalgo, New Spain (Dahlgren, 1883; Graham, 1907). In the simplified explanation of Waszkis (1993):

> Finely ground silver ore was mixed with water, salt, some [copper] sulfates and mercury. The resulting muck, or cake, was then stirred for days, by horses, mules or men, walking in it, wading in it, really kneading it. The process at times supposedly took up to 30 days. Water was then used to flush the lighter particles away. The amalgam of mercury and silver, or mercury and gold, remained at the bottom of whatever receptacle they used, and was collected, and heated. The mercury then evaporated, and pure, or almost pure, silver remained.

The chemistry was not really understood, of course, in the mid-16th century: from Medina on down to the technicians at the processing sites, everyone determined what worked from empirical methods alone. But the basic equations (Bakewell, 1984) for the patio processing of acanthite were as follows:

[1] $CuSO_4 + 2NaCl \rightarrow CuCl_2 + Na_2SO_4$
[2] $CuCl_2 + Ag_2S$ (=acanthite) $\rightarrow 2AgCl + CuS$
[3] $2AgCl + nHg \rightarrow Hg_2Cl_2 + Hg_{n-2}Ag_2$ (=amalgam)

The much-trampled sludge was roasted in small adobe furnaces to drive off and to recover the mercury. The ruins of these furnaces (*hornos*) were still commonly seen in old mining camps around Mexico in the early 20th century (Jenison, 1925). The refining

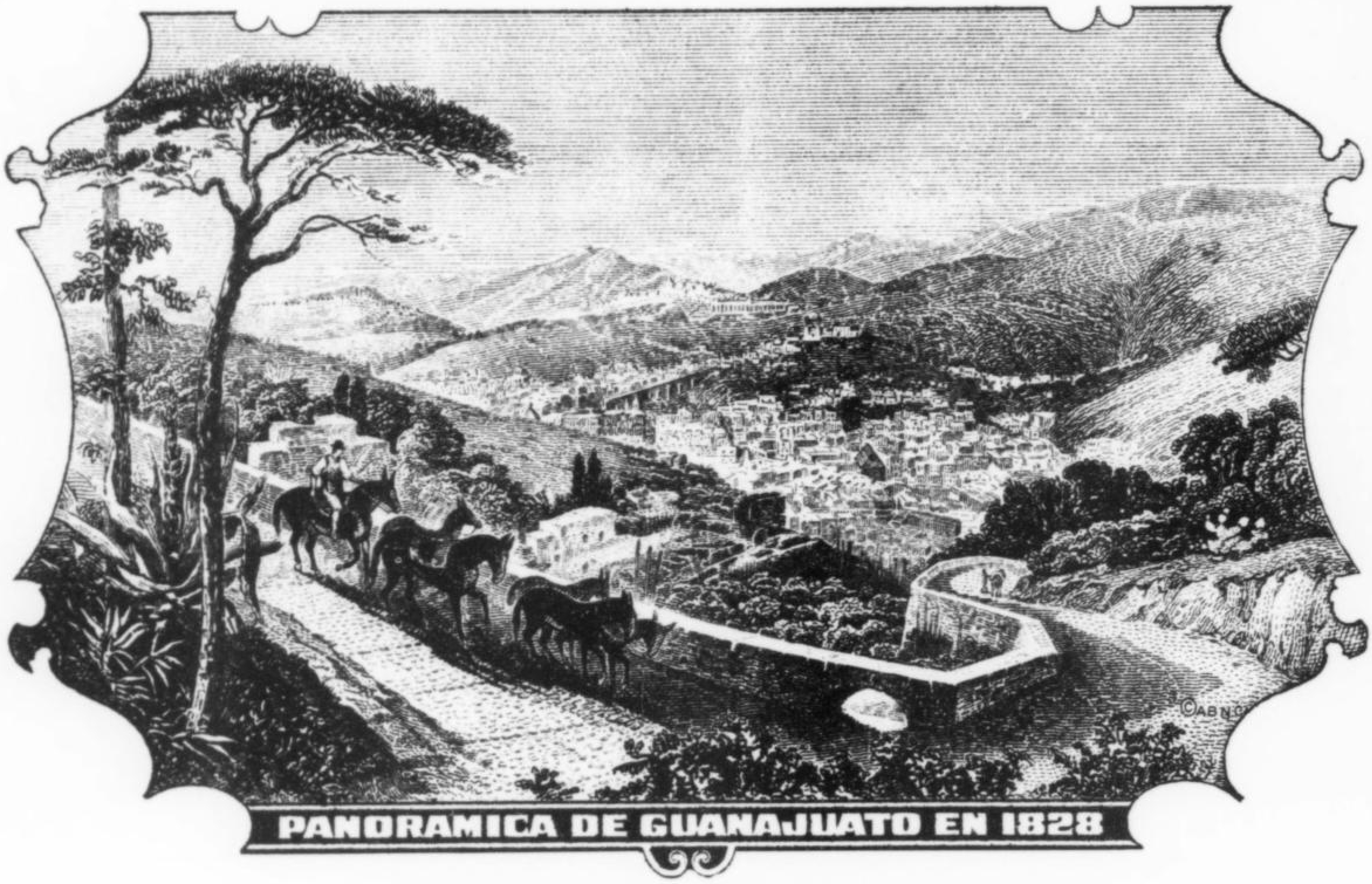


Figure 14. **An engraved panorama of the famous silver-mining city of Guanajuato in 1828, after an illustration in C. Nebel's *Voyage pittoresque et archéologique dans la partie la plus Intéressante du Méxique* (1836).**

facilities of which they were a part were known as *haciendas de minas* in Mexico and *ingenios* in Peru. By 1600 there were some 370 refineries in Mexico and 65 at Potosí alone. In the Andes a "hot" variant of the process was practiced, the ores being heated instead of just kneaded, in order to counteract the effect of the cold mountain air.

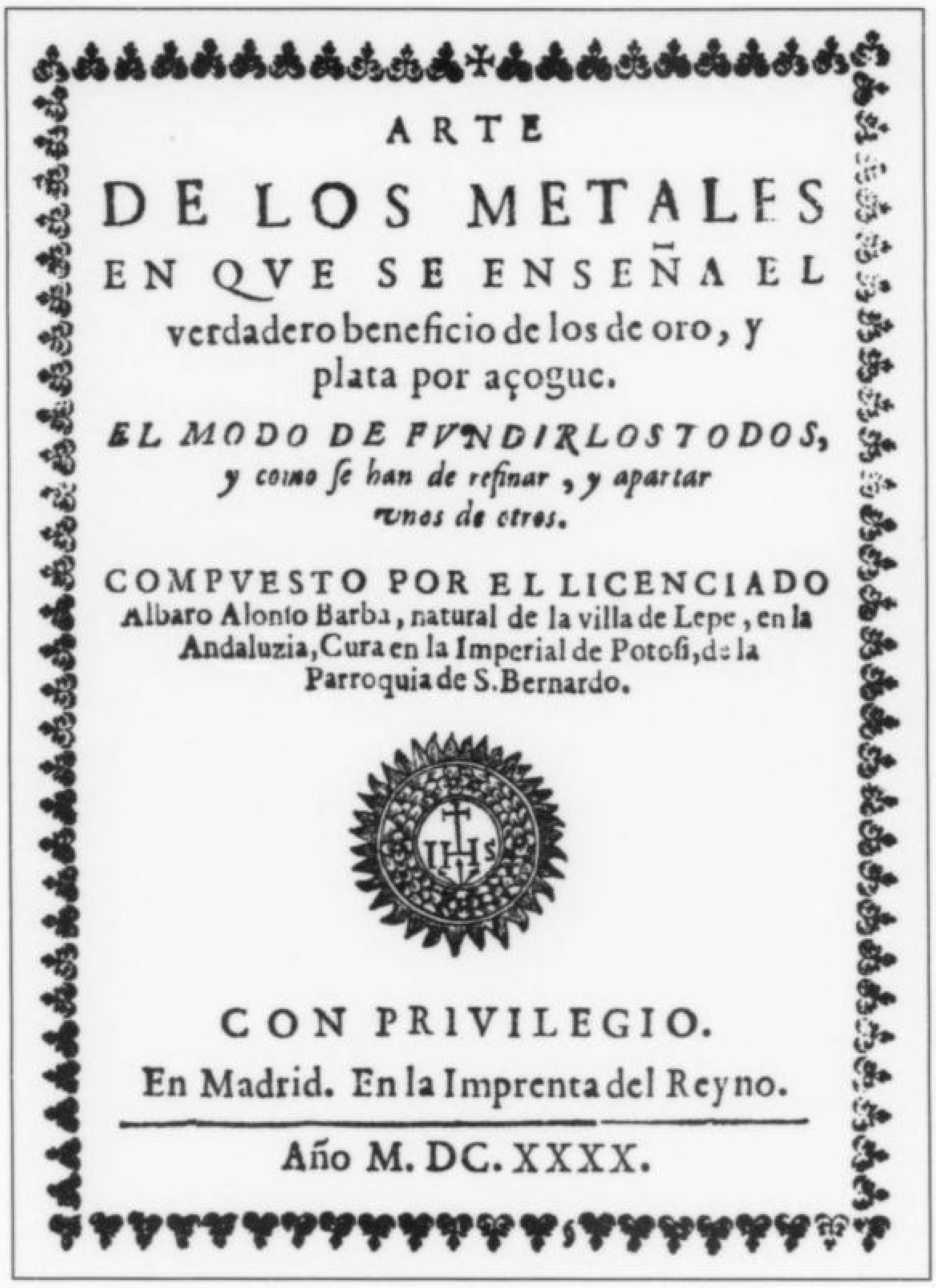
The success of the patio process meant that mining no longer was confined to near-surface bonanza ores; some lower-grade ores could also be worked economically. Further searches for new deposits were thus inspired, and, in general, the progress of mining and smelting technology after the 1550s successfully compensated for the inevitable decline in average ore grades. Every element of the patio process, by posing problems, challenged innovation. For example, to break up the ore finely enough to prepare it for kneading, stamp mills had to be designed. The most successful ore-stamping machines were simple but massive, consisting of heavy iron stamps lifted by camshafts and allowed to fall onto stone beds bearing the ore; the stamp shoes weighed up to 150 pounds. The mills were driven by water, horses, mules, or humans.

Ensuring supplies of the necessary chemicals for the patio process posed another set of problems. The copper sulfate (called *magistral*) was either mined from the upper zones of metallic deposits or obtained by processing chalcopyrite, but the iron for the stamp shoes, the salt, and the mercury had to be imported. Iron came mostly from Europe at first, but was generally in abundant enough supply; salt was easily gotten from evaporite deposits in northern Mexico and the central Andes. But the constant need for large supplies of mercury made for complex economics. After the period of Garcés' control of the Huancavelica cinnabar mine had elapsed, the Spanish Crown assumed monopolistic control of this and all other mercury sources to which it had access; by maintaining this control throughout the colonial period, the Crown maintained one of its essential powers over New World mining. Mercury came not only from the Huancavelica mine but also from the Almadén mine in Spain, and to a lesser extent from Idria, in modern Slovenia, then part of the Spanish/Austrian Habsburg domains. Production at Huancavelica peaked in the late 16th century, then dropped off gradually until the end of colonial times. Almadén's output was strong up to about 1620, and then again after a massive new orebody was discovered in 1698, but shortfalls in the mid-17th century account in part for the major decline in Mexican silver production during that time.

Hardly less important than Bartolomé de Medina in the history of silver mining technology in the New World was Alvaro Alonso Barba, a humble clergyman born in 1569. He studied for the priesthood in Spain, and was then was sent by the Church to South America in 1588. He is known to have been living in Lepas, Peru, in 1617, and was later transferred to Potosí, where he became pastor of St. Bernard's church.

Barba became interested in the mineralogy of the silver deposits and the refining processes used there to extract silver. Soon he began experimenting to discover better methods of extraction. He developed significant improvements in Medina's amalgamation process which made mining far more profitable. He advocated laboratory control of the beneficiation and refining processes, and he argued for analyzing all of the potential production costs before starting a mining operation.

Barba recorded all of his observations and discoveries in a manuscript (entitled *El Arte de los Metales*) which he presented in 1637 to Juan de Lizarazu, president of the *Real Audiencia de la Plata* of Peru, who in turn forwarded it to Spain—with the approval of the



ARTE
DE LOS METALES
EN QVE SE ENSEÑA EL
verdadero beneficio de los de oro, y
plata por açogue.
EL MODO DE FVNDIRLOS TODOS,
y como se han de refinar, y apartar
vnos de otros.
COMPVESTO POR EL LICENCIADO
Albaro Alonso Barba, natural de la villa de Lepe, en la
Andaluzia, Cura en la Imperial de Potosi, de la
Parroquia de S. Bernardo.

CON PRIVILEGIO.
En Madrid. En la Imprenta del Reyno.
Año M. DC. XXXX.

Figure 15. **The title page from Barba's famous (and famously rare)** ***Arte de los Metales*** **(1640), in which he described the minerals and ores of South America and various processing refining techniques which he developed for extracting silver from its ores. This title page is from the Herbert Hoover copy in the library of Claremont College.**

Figure 16. **A fine and extremely rare copy of Barba's** ***Arte de los Metales*** **(1640) in original vellum binding, offered last year by bookseller Jonathan Hill for $45,000.**

mayor of Potosí and the Amalgamator's Guild of Potosí. Realizing the enormous significance of his work, the Spanish government kept the information as a trade secret for as long as possible, publishing it in just a few copies in Madrid in 1640. This publication was the first significant Spanish-language treatise on metals, and is the only largely original 17th century work on that subject. The few surviving copies today are highly revered by book collectors. In later years it went through about 30 editions in Spanish, English, German and French (see Kuhner and Rizzo, 1980).

Barba died in Potosí in 1662, never having profited personally from his discoveries that helped bring incredible wealth to Spain. But he seems not to have minded; he took great enjoyment in the "qualities and virtues [of the many] marvelous substances of this New World [which] will afford ample room for philosophic discourses when the bright minds, now occupied in the tasks of taking out and enjoying the incomparable riches of this land, occupy themselves in the study of true science."

In such ways the Spanish enterprise in the New World progressed by innovation and made mining, always a complex business, dramatically more complex on a worldwide economic scale—dramatically more "modern," we might as well say. Far from remaining static and medieval for 300 years—as goes the stereotype—Spanish mining in the New World was an industry with continually evolving technology and attendant political, economic and social ramifications.

LABOR CONDITIONS

The predictable generalization, of course, is that the workers' lot in these mines constituted a highly unpleasant picture. However, "slavery" is too simple a term to describe it. After a short initial phase of true chattel slavery, three distinct systems for employing native Americans in the mines followed each other in succession, and although the term "slave labor" would come readily to a modern mind seeking to describe any of them, the fact is that conditions did slowly improve as the mines grew more rationalized and the times in general more humane. The horror story of the African slaves brought in from the time of Columbus onward is another—wretched and disgraceful—subject, but even here the apologist for Imperial Spain might point out that the African slave trade was a joint venture of all the mercantile European states, not just a project of "cruel, gold-crazed" Spaniards.

In 1494, Columbus himself suggested to Ferdinand and Isabella that the natives of Hispaniola and neighboring islands should be enslaved to gather gold. In fact, this was already happening, with the earliest colonists working thousands of natives to death in the alluvial gold deposits, using ferocious bloodhounds to track down slaves who resisted capture, or those who rebelled or fled. When it was clear that the aboriginal Indians were being wiped out by such treatment and by disease, it was suggested that slaves from Africa could replace them. In 1517, systematic slave trafficking from Africa to the New World began (Rickard, 1932).

But the Spanish Crown was never sympathetic to chattel enslavement of native Americans. Queen Isabella prohibited it in 1503, mandating that, except for cannibals and captives taken in war, the

Figure 17. **Indian prisoners employed as forced labor, cobbing out silver ore at a mine in Chihuahua; from Louis Simonin's *Life Underground, or Mines and Miners* (1869).**

Indians were to be treated "as free persons, for such they are." A series of anti-slavery edicts issued by the Crown culminated in one which closed most loopholes in 1548; the Crown had been moved by the pleas of some humanitarian friars and by the Papal Bull of 1537 declaring the Indians rational beings capable of becoming Christians. In general the policies of the Crown on Indian labor throughout the colonial period were much more humane than either the philosophical views or the actual practices of the governing class of Spaniards in the New World. The basic problem was to reconcile the Crown's intention of dealing kindly with the natives (and saving their souls) with the need for a stable labor supply in the mines and elsewhere.

The first solution was the *encomienda* system, begun by Governor Ovando of Hispaniola around 1500. A privileged Spanish colonist, the *encomendero*, received jurisdiction and manorial rights over certain lands and the people resident on them; he was obligated to serve as their protector and patron, in return for their unpaid labor. The scheme had evolved from the granting of such rights to heroes of the reconquest of Spain from the Moors, and many of the early New World *encomenderos* had been conquistadores, i.e. members of the most recent generation of warriors for Church and Crown. Essentially the system was feudal, and its tendency in the New World was to set up a permanent, semi-autonomous landed aristocracy. An *encomendero* could force any number of "his" Indians to work without pay in a mine he had claimed. The system provided no controls, was subject to many abuses, and was inherently destructive to Indian cultures even when the *encomendero* was not particularly cruel. Workers were removed from their villages, depriving the villages themselves of labor, making it harder for villagers to feed themselves, breaking up family lives, and all without guaranteeing any form of redress from the master.

The Spanish monarchs, again, were ambivalent, and in 1542 Charles V decided to abolish the *encomienda* system. His so-called New Laws of that year forbade slavery under any guise and forbade the granting of any new *encomiendas*. As the New World aristocracy saw it, this edict threatened to eliminate Indians as a source of free labor, and in fact threatened the whole culture of Spanish America. When Viceroy Blasco Nuñez de Vela arrived in Peru with the New Laws in 1544, a group of rebels led by Gonzalo Pizarro, the conquistador's son, assassinated de Vela and openly defied the Crown edict. The King's rule was not fully restored until ten years later.

The system defined by the New Laws was one which replaced forced tributary labor with forced paid labor (Haring, 1947). Called the *repartimiento* in Mexico and the *mita* in South America, it was a system of draft labor that brought the Indians under direct Crown control, bypassing the *encomenderos* (Lang, 1975). The exact terms of employment varied: in Peru, typically, a labor force from a village would be conscripted to work for six months or a year, then sent home for two years with some modest pay (Florescano, 1984). In transit between their villages and the mines and back, the workers had to provide their own food and accommodations (in effect, blankets to spread on the ground to sleep on); they were often flogged, and many died from exposure (Haring, 1947). The Quechua word *mita*, meaning time, turn, or term of time, had been used before the Spaniards arrived to describe forms of slavery imposed on the Quechuas by the Incas (the Aztecs in Mexico had had similar labor drafts for their own subject peoples), and surely the Spanish system

***Figure 18.* Indian miners in Mexico, from Louis Simonin's *Life Underground, or Mines and Miners* (1869).**

looked from below simply like a continuation of slavery. The largest single *mita* of the 16th century was organized in 1572 in Peru by the viceroy Don Francisco de Toledo, to supply the Potosí mines. Toledo went about the Andean towns fixing quotas of workers, and in each town lots were drawn to determine those who should work for a year at mining operations. Conditions at the mines were so difficult and the treatment of the laborers so severe that drawing a *mita* lot came to be regarded as almost the equivalent of a death sentence. Men and women were required to marry early in order to keep up the labor supply by breeding (Bain and Reed, 1934).

To spare their children from being drafted in the *mita* for the notoriously awful Huancavelica mercury mine, Indian mothers would sometimes deliberately break the childrens' legs (Wallace and Hall-Wallace, 2003).

In 1601 the Crown again attempted reform, stating its ideal desire for a voluntary, paid workforce in mining (Bakewell, 1984). Actually, there had been from the start some Indians who volunteered to work in the mines and to receive specialized training in return for pay. Especially in northern Mexico, where the original populations were too sparse and/or too rebellious to make the earlier systems fully workable, voluntary wage labor had supplemented the *encomiendo* and draft systems from the earliest times (Bakewell, 1984). By the latter 16th century the *mita* had begun to evolve spontaneously, throughout the empire, into a system of peonage whereby mine owners would give advances of money or goods to Indian workers to induce them to move, with their families, out of their villages and take up residence at the mines. The old laws defining the *mita* system remained in effect, but were often ignored as the old ways yielded to newer, less lethal ones. By this time many Indians with long experience in mining had acquired technical skills, and could bargain successfully for higher wages. Native Indians, freed African slaves, and *mestizo* (mixed-breed) laborers began to form a sort of miners' caste, with sons inheriting the mining profession from their fathers, and after its 1601 pronouncement the Crown made a few laws to guard the welfare of these quasi-professionals. Many, in time, even came to live stable, fairly affluent, Europeanized lives in the urban centers around the great mines.

But throughout this evolution from chattel slavery to professionalism, working conditions at the mines remained harsh. It is estimated that in 1521, when Cortez arrived, the population of Mexico was 11 to 25 million, and by 1603 it was a little over 1 million (Waszkis, 1993). Certainly the chief depopulating factors were yellow fever, measles, typhus, swine flu and malaria, but the mining industry contributed to the calamity, since the work in the mines lowered resistance to disease. Jenison (1925) quotes a Spanish observer of a plague season around some Mexican mines: "The number of deaths was so great that corpses bred pestilence and for half a league around a certain mine and on the greater part of the road to it, one could scarcely make a step except upon dead bodies or the bones of men, and the birds of prey coming to feed upon these corpses darkened the sun."

At the mines many workers went blind in the dust and glare of the patios, or got fatally ill from breathing mercury vapors. In the high Andes, the constant shuttling of ore-bearers between the heat of the deep workings and freezing temperatures at the surface typically caused respiratory disease. The hauling of ore—in rush baskets, hide buckets, sacks, or llama-wool blankets—was certainly the most awful work of the mines. The ascents were made along steps hacked into the rock or on notched tree trunks, bad ground gave way constantly under the haulers' feet, and the ore sacks often had to be filled to weights of up to 300 pounds (Bakewell, 1984). Interestingly, Graham (1907) notes that among the sufferers there were a few special prisoners of the Inquisition: English "Lutheran dogs" captured from the ships of John Hawkins and Francis Drake, and condemned to labor in chains in the mines of Pachuca, Taxco and Zacatecas.

In later times, when mining families had come to pass down the profession through succeeding generations, the work became less cruel than it was simply routinized, a predictable life's course of labor. Dahlgren (1883) described the routine as it was in Mexico during the mid to late 19th century, but the description surely applies as well to the latter part of the Spanish colonial period. A boy from a mining family began as one of the platoons of *zorrillos* (literally, "little skunks") who brought tools and supplies to the miners and ran errands. Next he became one of the *tenateros*, who carried ore out of the mines in heavy ore sacks (*tenates*) strapped across the forehead and hung down the back. For most of his adulthood he was one of the *barreteros*, miners who drilled shot holes and dug ore underground. As an old man he joined the ranks of the *limpiadores*, ore-sorters who worked on the surface processing the ore. The work at all stages was dull, and at most stages physically hard, but it provided a living and bespoke stability, linking workers to their families' pasts and to the folk-life of the nation.

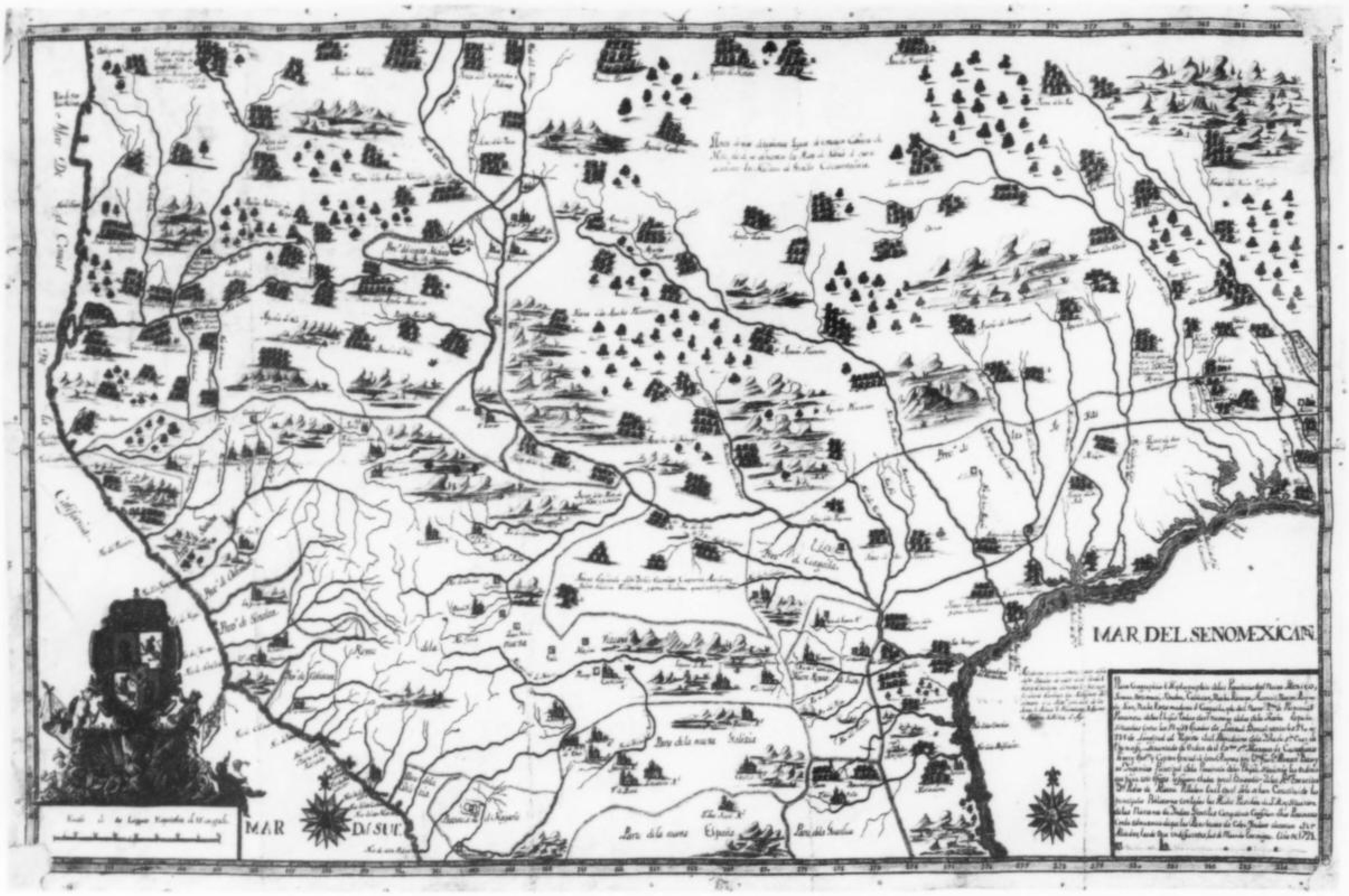


Figure 19. **The first map ever made by a trained cartographer (Francisco Alvarez Barreiro, 1728) of the northern provinces of New Spain. Hispanic Society of America collection.**

THE BUSINESS OF MINING

Mining law in the New World reflected principles which had already evolved in Spain. By the first and most fundamental of these principles, all mineral deposits, like all lands in general, belonged to the Crown. However, the law encouraged private entrepreneurship by giving prospectors the right to claim and exploit deposits "in usufruct," i.e. to work them under concessions and contracts, conditional only on payments of taxes and royalties to the Crown. Prospectors could seek deposits freely on public and private lands, and their freedom to work their claims and to refine ore was unfettered as long as they paid their Crown royalties. A mine had to be actively worked if a claim to it was to remain valid. A claim encompassed not only the surface outcrop but all minerals encountered at depth. These very liberal (for the times) principles were quite well suited to finding and developing deposits in the New World. The earliest Crown pronouncements attempted to apply the old law from Spain that the discoverer of a deposit could keep only one-third of the resulting profits, the rest to be paid to the Crown, but very soon the prospector/owner's share was increased to one half, then four-fifths. For nearly the entire colonial period the Crown's standard portion was one-fifth, the *quinto real*, regarded not as a tax but a royalty (except in cases of royal monopolies such as that on the Huancavelica mine). These basic laws were enshrined for Mexico in 1550, in the Code of the Viceroy Antonio de Mendoza, and the same laws, with minor variations, were promulgated for Peru in 1574, by the Code of the Viceroy Francisco de Toledo (Prieto, 1973).

In 1584, Philip II issued a comprehensive mining code for both Spain and the New World, reaffirming the principles outlined above and extending wide-ranging privileges to the discoverers and exploiters of silver mines, giving them great leeway in conducting their businesses (Prieto, 1973). The 1584 code remained in effect for almost 200 years, and even when the so-called New Code of 1783 was issued, it remained based in great part on the policies of the old code. The laws of 1783, in turn, endured for another century—for the rest of colonial times and for the first 70 or so years of independence. Another sign of the progressive, practical, far-sighted nature of the administration of New World mining is that mints were established at early dates (1536 in Mexico, 1568 in Lima, 1572 in Potosí) for converting some of the newly mined silver and gold into usable coinage.

The disadvantage of the generally *laissez-faire* mining policies of the Crown is that they made raising capital for the mines a loose, inefficient business. Before Medina developed the patio process, little capital was required to develop a mine, as the near-surface ores were easily extracted and smelting furnaces were inexpensive. But when the patio process made possible deeper mining for lower-grade ores, and extensive refining facilities had to be built, and mercury had to be purchased from the Crown monopoly, large amounts of capital suddenly were required. In Zacatecas or Potosí in the early 17th century, a *hacienda de minas* might cost between 10,000 and 50,000 pesos (Blakewell, 1984). For a while, considerable monies could be raised by amalgamating the ores previously discarded as too poor for smelting, but such autonomous financing lasted no more than two or three decades in any district (Blakewell, 1984).

Enter, at this point, the merchant community in mining centers, out of which came the *aviadores*, who loaned cash or supplied credit to the mine owners. As repayment the *aviador* accepted refined but unminted silver, and with monies gained from the interest on loans

***Figure 20.* An engraving of the School of Mines in Mexico City, opened in 1795, from Calderon de la Barca's *Life in Mexico during a Residence of Two Years in that Country* (1843).**

he shipped the silver to the nearest mint to have it converted to coinage, and may in some cases also have paid the *quinto real* Crown royalty on the ore. Mine owners, of course, routinely denounced the usurious practices of these middlemen. Jenison (1925) guesses that the *aviadores* made more profits than the mine owners most of the time; on the other hand, the merchants often had to absorb bad debts, and the guess of Blakewell (1984) is that "the number of prosperous *aviadores* in any center at any moment was probably no greater than the number of prosperous silver producers."

A hierarchical system of middleman-dealers finally evolved, with major silver merchants—in effect, bankers—at the apex, and lower-level "ore buyers" mediating between them and mine owners. By this loose arrangement the banker would fund the ore buyer(s), who would buy ore at the mine, then sell the ore or the silver extracted from it to the banker, who would resell it at a considerable profit. Around 1780 the Crown began to establish its own "mining banks" for purchasing silver directly, but financing by layers of merchants and merchant-bankers continued to predominate until the end of colonial times (Blakewell, 1984). In the late 18th century Charles III set aside considerable revenues from Crown taxes to be held in a mining bank in Mexico City, but these monies were appropriated by the mother country when the Napoleonic wars broke out, and thus they were lost to mining in the New World.

Despite the ramshackle economics, the Mexican mining industry peaked near the end of colonial times, Mexico producing between $20,000,000 and $25,000,000 in gold and silver each year (Jenison, 1925). Through the middle part of the 17th century Mexican silver production had stagnated, partly because of the decimation of the native labor pool, partly because of the diversion of Almadén mercury from Mexico to Peru as the Huancavelica mine declined. Nevertheless, thanks to more rational mining techniques, especially the mushrooming use of underground blasting, Mexico superseded Peru as the world's greatest silver-producing country in 1680, and between 1790 and 1810 an impetus from the new Mining Academy in Mexico City led to a flurry of exploration which located many new deposits. In short, the mining industry in Mexico flourished mightily in the years just before 1809, when Napoleon invaded Spain.

Silver production from Peru (including "Charcas," or Bolivia) between 1601 and 1760 averaged 3,250,000 ounces yearly (Bain and Reed, 1934); Peru led the world in silver production between 1661 and 1680. Here, too, production peaked just before independence, with almost 5,000,000 ounces being produced in each of the years between 1801 and 1810. The Potosí mine, previously in decline, tripled its silver output between 1720 and 1780; Oruro and Cerro de Pasco were booming at the same time. In general, in the Andes as in Mexico, capital investments increased and mine technologies improved during the last century of Spanish rule. By the time the Wars of Independence broke out, silver mining in the New World had reached a pinnacle of prosperity and economic importance.

CONCLUSION: THE FINAL CENTURY

The stability and modernity of the silver mines and infrastructures which were inherited by the new Latin American states are well symbolized by the great "underground city" (as one observer called it) of the Valenciana silver mine in the Guanajuato district, Mexico. By the late 18th century this mine had masonry-reinforced galleries, vertical shafts to 1800 feet deep, and an enormous complex of adits. It employed some 3,300 underground workers and produced 70% of the district's silver (Bakewell, 1984). Modern scientific and technological brainpower for this tremendous mine and for Mexican silver mining generally were supplied by the Mexican Mining Academy, opened in 1795, an outgrowth of the reformed

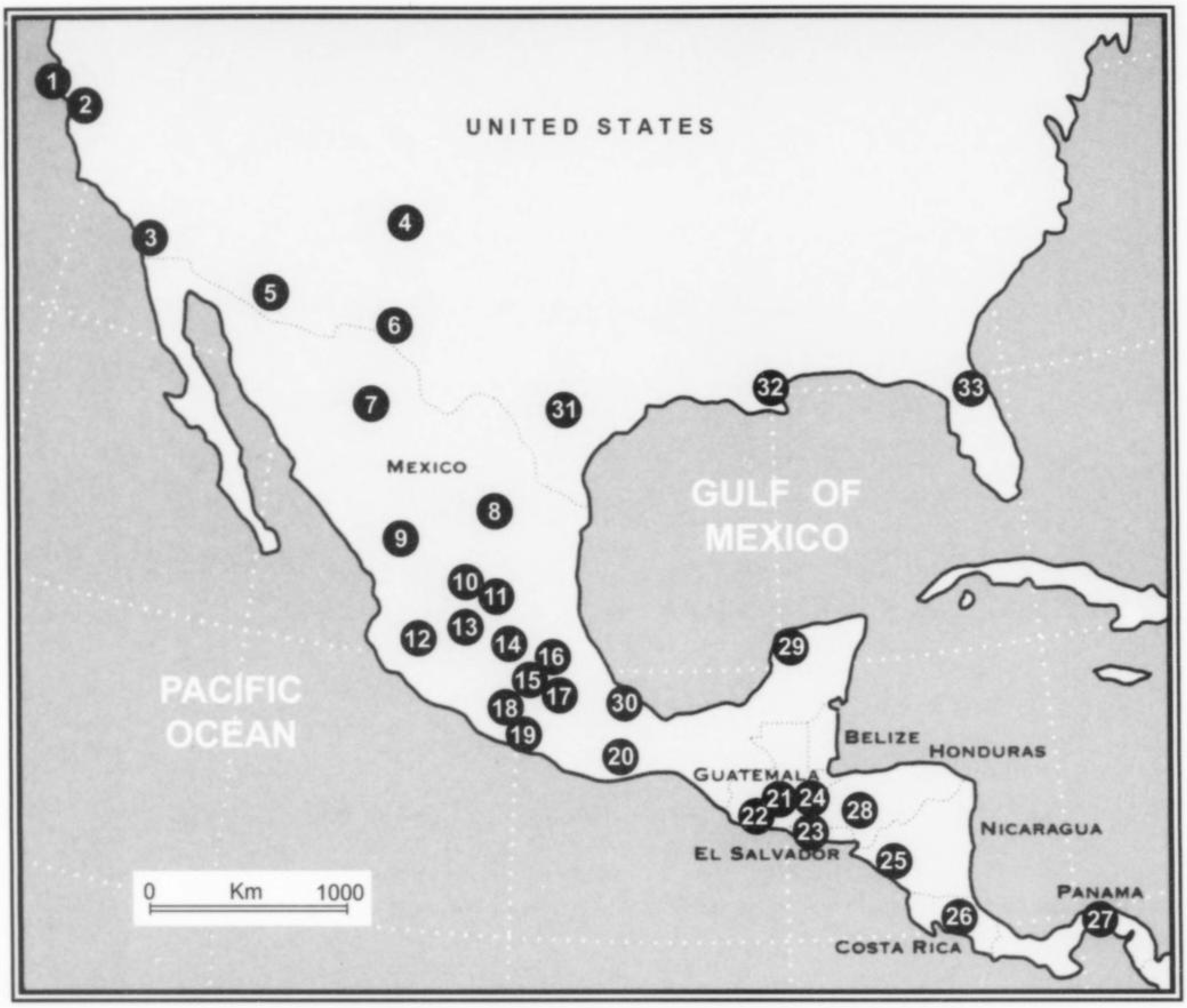


Figure 21. **The Viceroyalty of New Spain and its various administrative centers, many of which were also prominent centers of silver mining:**

1. San Francisco
2. Monterey
3. San Diego
4. Santa Fe
5. Tucson
6. El Paso
7. Chihuahua City
8. Saltillo
9. Durango
10. Zacatecas
11. San Luis Potosí
12. Guadalajara
13. Guanajuato
14. Querétaro
15. Mexico City
16. Acolman
17. Puebla
18. Taxco
19. Acapulco
20. Oaxaca
21. Guatemala City
22. Antigua
23. San Salvador
24. Esquipulas
25. Managua
26. San José
27. Panama City
28. Tegucigalpa
29. Mérida
30. Veracruz
31. San Antonio
32. New Orleans
33. St. Augustine

mining code of 1783. The first director of the Academy, and a prototypical man of the times in Spanish America, was Fausto de Elhuyar, educated in Paris and at the Mining Academy of Freiberg, Germany. Until the Mexican War of Independence (which he did not support), Elhuyar saw to it that the Academy in Mexico City was on a par with the mining schools of the Old World, and not incidentally he built a mineral collection for it (see Wilson, 1994). Another European-trained scholar, Manuel Andrés del Río, who worked with Elhuyar at the Academy, also furthered the mineral collection there, as well as writing a book on the elements of mineralogy (*Elementos de Orictognosia*) in 1795 and, in 1801, discovering the element vanadium in vanadinite from the Cardonal mine in Zimapán, Hidalgo (Wilson, 1994). Unlike Elhuyar, del Rio was a Mexican patriot who supported independence. Four of his prize students at the Academy joined a movement of insurgent workers at the Rayas and Valenciana mines when they rallied for independence in 1810, and when these four students were captured and executed, del Rio attempted to name new mineral species after them, although unfortunately the species did not prove to be valid (Prieta, 1973).

Silver mining in the New World ended, in its Spanish form, not from internal causes but as the result of external political forces. Spain by now was a pawn in the power game between Britain and Napoleonic France, and the colonies had matured to the point of aspiring to independence. The Spanish-controlled trade routes founded in New World silver and encircling the world (thanks to the lonely 300-year-old traffic of Manila galleons between Mexico and the Spanish Philippines) would be replaced by more modern commercial arrangements, and the cosmopolitan commercial fairs of Potosí would become images of a golden past.

Undeniably, a sense of the dead and decently buried past, to which we have said good riddance, hovers about all accounts of Spanish imperial activities in the New World. There is little trouble in granting that the conquistadores and most of their immediate heirs were essentially pirates and plunderers, and "behind them rose the smoke of ruin and the dust of desolation" (Haring, 1947). But the lore and lure of fabled treasure—talismanic of romance, curiosity, and even of some ideal quest for beauty—should not be hard for anyone, least of all mineral collectors, to understand. Human nature leaves cairns everywhere, and its adits in time go deep.

ACKNOWLEDGMENT

My thanks to Wendell Wilson, who located and researched all of the illustrations for this article.

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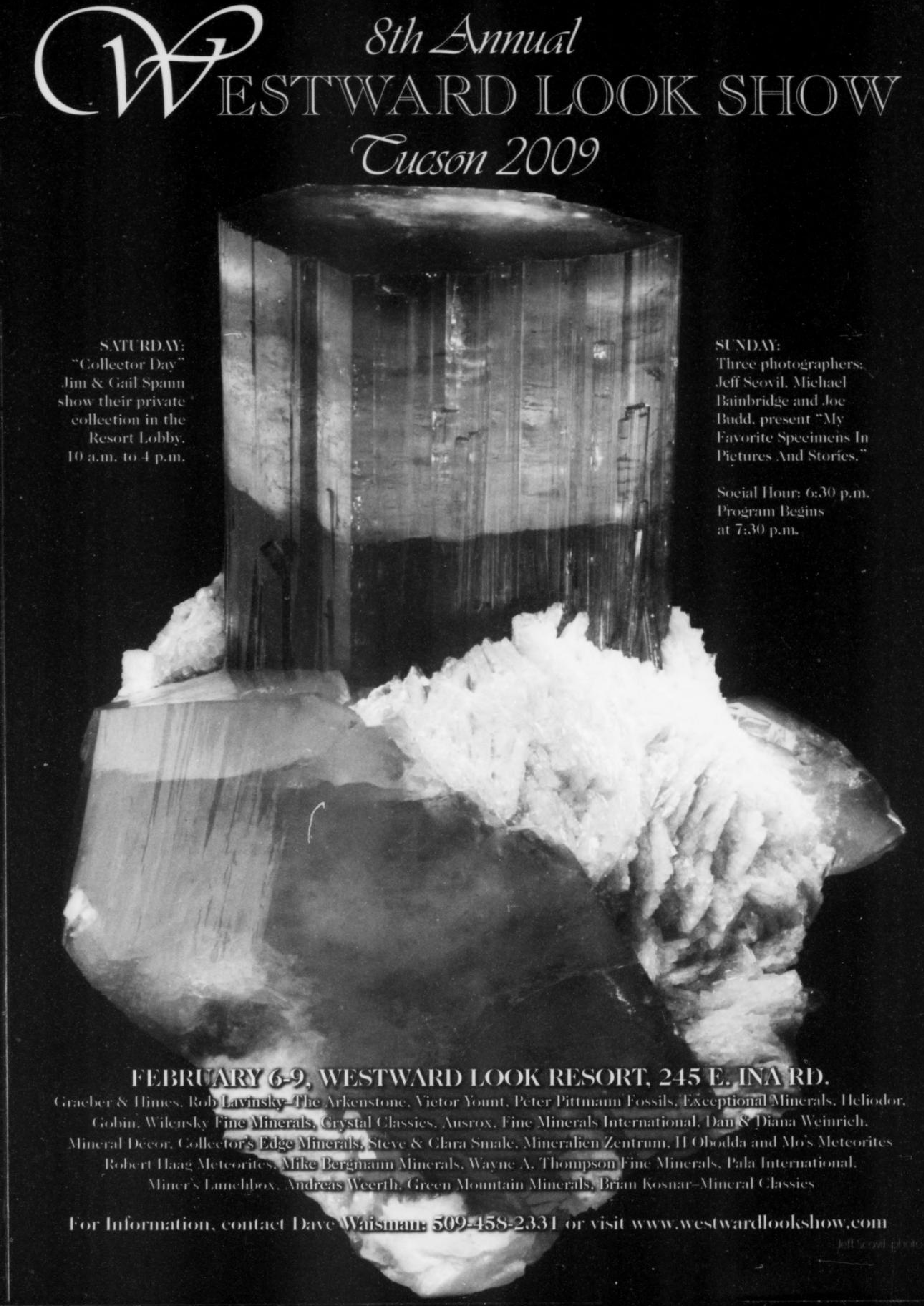
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WESTWARD LOOK SHOW
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Jim & Gail Spann show their private collection in the Resort Lobby. 10 a.m. to 4 p.m.
SUNDAY:
Three photographers: Jeff Scovil, Michael Bainbridge and Joe Budd, present "My Favorite Specimens In Pictures And Stories."
Social Hour: 6:30 p.m.
Program Begins at 7:30 p.m.
FEBRUARY 6-9, WESTWARD LOOK RESORT, 245 E. INA RD.
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For Information, contact Dave Waisman: 509-458-2331 or visit www.westwardlookshow.com

Famous Mineral Localities:

The Milpillas mine

Cananea district, Sonora, Mexico

Thomas P. Moore
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Outstanding azurite crystals and malachite pseudomorphs from the Milpillas copper mine began appearing on the mineral market in 2006. At their best, these specimens compare well with classics from Bisbee and Morenci, Arizona, and even with those from Tsumeb, Namibia. The huge new underground mine exploits a manto deposit of chalcocite, with secondary copper minerals occurring in brecciated volcanic country rocks. Prospects are good for continued specimen production during the next few years, as long as the mine remains in operation.

LOCATION AND SETTING

The Milpillas copper mine is located under a flat, gravelly tract of ground called Rancho Milpillas, 25 kilometers northwest of the mining town of Cananea and 45 km southeast of Nogales, Arizona/Sonora, about 20 km due south of the international border. The nearest settlement is the miners' village of Cuitaca, 17 km south of the mine. From Arizona the mine is best reached by driving due south from Nogales to Imuris, then turning east onto a good blacktop road to Cuitaca. From there a good dirt road runs to the mine.

Milpillas is the diminutive form of the Spanish word *milpa*, ("corn field"), but in fact the terrain for many kilometers around the mine site is fallow-looking and dry, with long views to scantily wooded horizons off to the south and few signs of habitation. The people most commonly seen on the road from Imuris to the mine are road workers who park their trucks dangerously on the narrow, curving, two-lane road while they jump out to remove rock-fall rubble which has fallen onto the blacktop. During the rainy season, vaporous, silvery streams and mini-waterfalls are seen threading the steep cliffs and cuts above the road; while these are picturesque they also signal danger, as their erosional power may trigger further rock-falls.

Few visitors are granted entry to the Milpillas mine, and those who are admitted are closely supervised, both at the surface and underground. The mining company sternly discourages visits from crystal buyers, and is not sympathetic to miners who collect crystals from pockets and smuggle them out for sale. In these respects the mine is like many others, but because of its proximity to the U.S. border, other dangers also come into play. It is said that a local drug

Figure 1. **Location map.**

lord controls the road from the mine at night, and trades drugs for azurite, or vice versa. One recent (typical) story has it that a Mexican mineral dealer who had had some success at the mine was stopped at 4:00 a.m., forced to get out of his truck, and beaten unconscious; when he came to in a hospital four days later he found that all of his money was gone, as were four excellent cabinet-size azurite specimens and some smaller specimens. The recent film *No Country for Old Men*, and the novel of the same name by Cormac McCarthy, evoke what seems to be going on: our imaginations need only add mineral treasures to the motivational mix. Let us hope that, in time, better days will come to these dangerous borderlands.

HISTORY AND PRESENT OPERATION

The Milpillas manto and porphyry copper deposit is located in the Cananea mining district, one of the largest porphyry copper districts in North America. To date the mines of the district have produced more than 3.5 million tons of pure copper (Valencia *et al.*, 2006). Major copper deposits include those at Los Alisos, El Toro, El Alacran, La Piedra, La Verde, Mariquita, three orebodies at Cananea, the orebodies exploited by the Lucy and María mines, and finally, on the district's northwestern edge, the Milpillas deposit, where mining began in 2006.

The Milpillas deposit was not discovered until just recently because it lacks surface expression, being indeed "the prime example of a hidden deposit in Mexico" (Valencia *et al.*, 2006). In 1978, exploration began to focus on Rancho Milpillas, in part as a follow-up to some regional stream-sediment sampling which had been done by the U.S. Geological Survey in 1975. The sampling found float examples of quartz-sericite alteration, hinting at porphyry-copper mineralization below. It turned out that the float had been transported from elsewhere and bore no relation to the Milpillas deposit, but it inspired Minera Cuicuilco, a subsidiary of Cyprus AMAX (allied with Grupo Peñoles) to conduct extensive test drilling, and this revealed hidden horizons of ore under 300 to 500 meters of gravel and alluvium. During the 1990s, optimistic figures on ore reserves were reported by two American mining consultants, who were nevertheless concerned that mining through the deep overburden might not prove economically feasible. One consultant, Michael Clarke, then Mexico Exploration Manager for Cyprus AMAX, suggested that underground mining of high-grade oxidized ore could be used to bootstrap later open-pit mining of lower-grade ore.

In 1998, Grupo Peñoles acquired the property, and in 1999 an exploration program was conducted by Peñoles S.A. de C.V. (the world's leading producer of silver and one of Mexico's largest and most diverse mining companies) and Chile's Codelco (the world's leading producer of copper). Subsequently more than 100,000 meters of test drilling, first by Minera Cuicuilco and then by Grupo Peñoles, established that underground mining would indeed be economically feasible if combined with on-site operation of a large copper solvent extraction (SX) plant. In 2001 the "Milpillas Copper Project" was launched, mining start-up was scheduled for late 2005, and in July 2006 the SX plant was commissioned from the Cytec company by Compañía Minera La Parreña, the subsidiary of Grupo Peñoles which operates the mine.

Cytec's plant, more properly a "leach-solvent-extraction-electrowinning facility," is designed for a production rate of 65,000 tons of cathode copper per year, though it is expected to produce only 45,000 tons per year during the first four years of the project (Pacheco and Noyola, 2007). In the plant, a branching, very complex set of mechanical and chemical processes extracts copper from the Milpillas ore. The crude ore is crushed to an average grain size of 2 cm, and the finer-grained material is bathed in dilute acid and sent to permanent leach heaps (these heaps cover an area of about 600,000 square meters), while coarser-grained material yields to "electrowinning," i.e. electrolytic extraction of copper, with deposition of the metal on banks of stainless steel cathodes. In seven-day cycles these cathodes are "harvested," i.e. a great machine on a crane arcing over the electrowinning tankhouse lifts the cathodes out. Then the copper is washed, stripped, stacked, weighed, sampled, corrugated, strapped and labeled for shipment. Most of the technical workers in this ultramodern facility have been drawn from the mining community at nearby Magdalena, Sonora. No comparably high-tech facility exists there, but a *Cytec* publicity document boasts that the training of workers for the Milpillas Copper Project has been most careful and thorough.

Today that project, incorporating the underground mine and the SX plant, is Grupo Peñoles' most advanced mining operation, and the mine itself is Peñoles' first wholly owned copper mine. As mentioned, mining start-up was initially scheduled for late in 2005, but soft, sandy ground was encountered and extra measures had to be taken to ensure stability and guard the miners' safety. Thus the first ore mining was delayed until early in 2006, and as of mid-2007 the production of cathode copper had not yet reached its targeted level.

GEOLOGY AND MINERALIZATION

The Cananea mining district is part of a great metallogenic province, economically one of the world's most important, which lies near the southwestern edge of the North American tectonic plate. This province, reaching well into the Basin and Range area of the southwestern United States, contains more than 50 major deposits of copper, molybdenum, gold, silver and other metals, including, of course, the great porphyritic/hydrothermal copper deposits of Bisbee, Morenci and Ajo, Arizona.

In the Cananea district, the basement rocks consist of Pinal Schist and related granite intrusions of Precambrian age (the Cananea Granite has been dated at 1.48 to 1.41 billion years old). Overlying this basement are early Paleozoic sedimentary rocks, representing the Sonoran extension of the Cordilleran miogeosyncline and platform

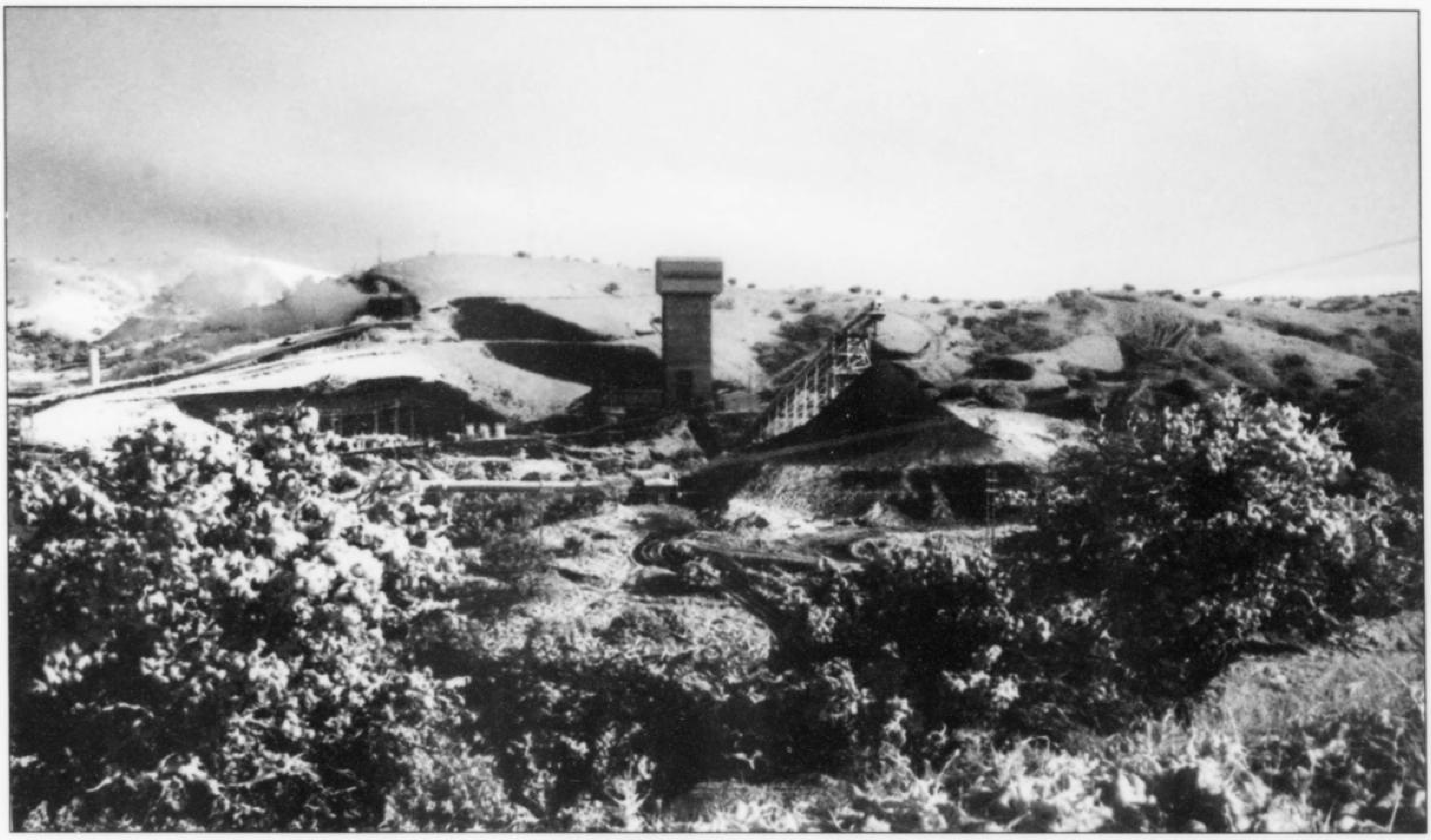

Figure 2. **The Milpillas mine site (photo courtesy of Salvador Ortiz and Francisco Quintana, Peñoles Company).**

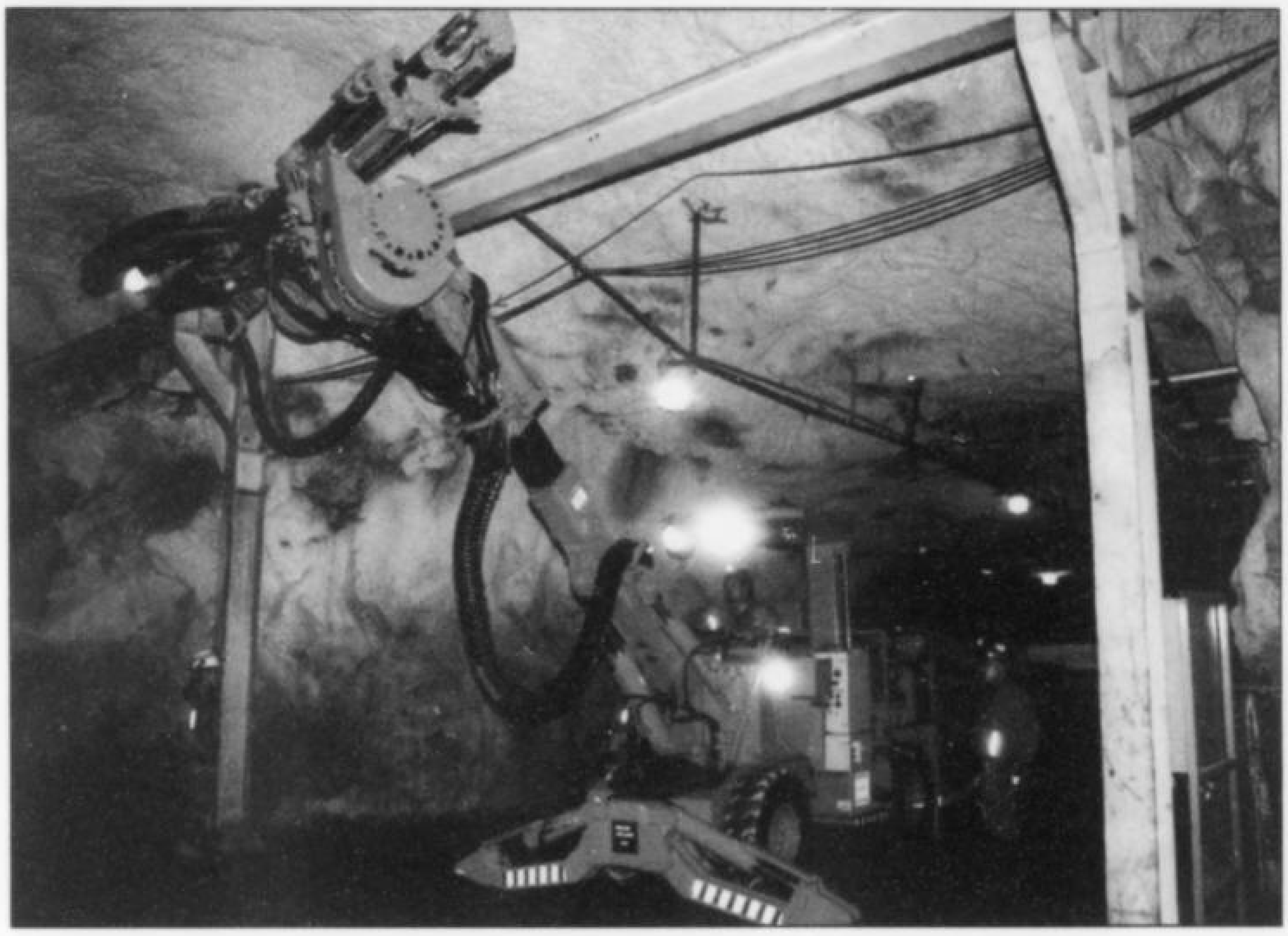

Figure 3. **Mechanized drilling equipment underground at the Milpillas mine (photo courtesy of Salvador Ortiz and Francisco Quintana, Peñoles Company).**

sequences. Resting unconformably on these units are volcanic rocks of the Elenita (Triassic-Jurassic) and Henrietta (Jurassic) Formations, both intruded by plutons of Jurassic age—the extrusive rocks are the remnants of a volcanic arc which once extended from California into the Mexican state of Durango. Plutonic and volcanic rocks of the Mesa Formation were emplaced during the Laramide Orogeny in Late Cretaceous-Paleocene times. Indeed, most of the porphyry copper deposits of southwestern North America are associated with that orogeny, which is characterized by zones of crustal extension of Basin and Range type. In the Cananea district, crustal extension is represented by the 7 km-wide, down-dropped block called the Cuitaca Graben, in which the Milpillas orebody rests.

In the Oligocene (30 to 25 million years ago), further volcanic sequences were laid down, and during the Miocene, with the relaxation of confining stresses at the North American-Pacific Plate margin, disruption and rotation of the Cananea district was caused by widespread crustal extension in Sonora (27 to 12 million years ago). Tertiary and Quaternary gravels and alluvium today cover the Cuitaca Graben, rendering the Milpillas deposit "hidden," although close to the graben's eastern edge there is a small horst where a few outcrops of altered and oxidized ore give the only surficial signs of an underlying deposit.

Secondary copper mineralization in the Cananea district is hosted by stocks of rhyolite and quartz monzonite porphyry which were intruded during the Laramide Orogeny in Late Cretaceous-Paleocene time. The porphyry stocks consist of 2-mm to 5-mm quartz, feldspar and biotite phenocrysts in quartz and orthoclase, overprinted by strong sericitic alteration. These intrusions, and

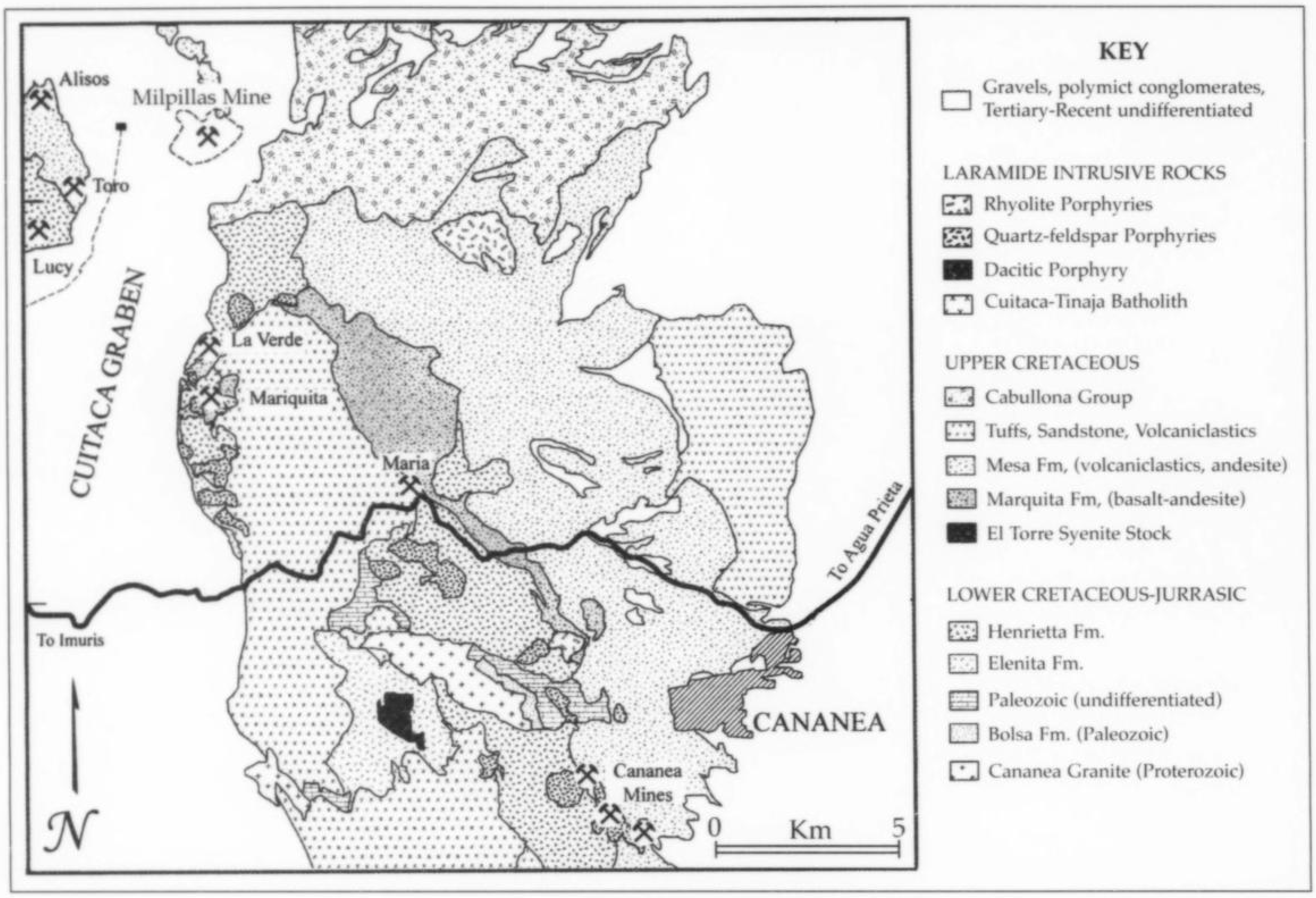

Figure 4. **Geologic map of the Cananea mining district (modified from Noguez-Alcántara—in prep.).**

the hypogene copper mineralization which closely followed them, probably emanated from a Laramide-age batholitic pluton complex locally known as the Cuitaca-Tinaja batholith, dated at about 63.9 million years by U-Pb zircon geochronology. Re-Os molybdenite chronology from the Milpillas orebody gives an age of 63.1 million years, establishing that the Milpillas porphyry copper deposit, the oldest of the copper deposits of the Cananea mining district, formed very soon after the intrusion of the hosting porphyries. The Re-Os data further suggest that hypogene mineralization in the Cananea district occurred in three discrete pulses at 63, 61 and 51 million years ago—in contrast to a previous model which had postulated that the mineralization had been continuous over a period 62 to 52 Ma (Valencia *et al.*, 2006).

In the Cananea district in general, hypogene copper mineralization is present as sulfides disseminated in breccias and stockworks. Where pre-Laramide sedimentary host rocks were present, skarn mineralization formed high-grade but low-tonnage orebodies, as in the mines near Cananea. At Milpillas, low-grade hypogene mineralization is present, but supergene enrichment later formed irregular sulfide bodies, primarily of chalcocite. These supergene chalcocite zones, manifested as subhorizonal blankets with upper leach caps, reach ore grades ranging from 1% to more than 10% copper.

At least three cycles of secondary enrichment are recognized; these have resulted in at least six chalcocite blankets at depths of 150 to 750 meters below the surface. The upper three blankets primarily contain oxide mineralization; below them is an intermediate horizon with secondary species mixed with primary sulfides; the two deepest blankets contain chiefly chalcocite and minor covellite.

THE UNDERGROUND MINE

Just beyond the entry gate to the mine complex and off to the right there is a cluster of modest-looking administrative buildings and miners' support facilities. Beyond are banks of mine tailings above which tower the headframes and great aerial conveyer belts. At the heart of the complex at the top of the hill lies a huge enclosed plant for leach-solvent-extraction of copper from ore, and adjacent to this is another administrative/support building. The mine is entered through a single concrete-lined portal, where very large trucks transport miners in and raw ore out. The steep truck roads branch downward almost immediately from the portal, and a furious din of engines is all around. The heavily laden ascending trucks enjoy right-of-way over the descending ones, and so the latter must frequently lurch or back off into cul-de-sacs and wait while the loaded trucks labor upwards past them in the roaring gloom.

The mine's upper levels are marked by huge mined-out stopes, each stope supported by pillars of country rock 8 meters thick. The walls and pillars are mostly red and white mottled andesite and quartz monzonite with green veins of chrysocolla and malachite showing in many places. At a few sites around the walls are narrow seams of white clay in which occasional blue spots may hint of azurite crystal pockets within. From below the hollowed-out stopes come rumbles of ongoing mining in deeper, richer horizons of ore. These depths (absolutely off-limits now to visitors) contain about 230 million tons of sulfide ore grading 0.7 to 0.9% copper, plus about six million tons of enriched, oxidized ore grading 4% copper (1994 estimate quoted by IMDEX, 2008).

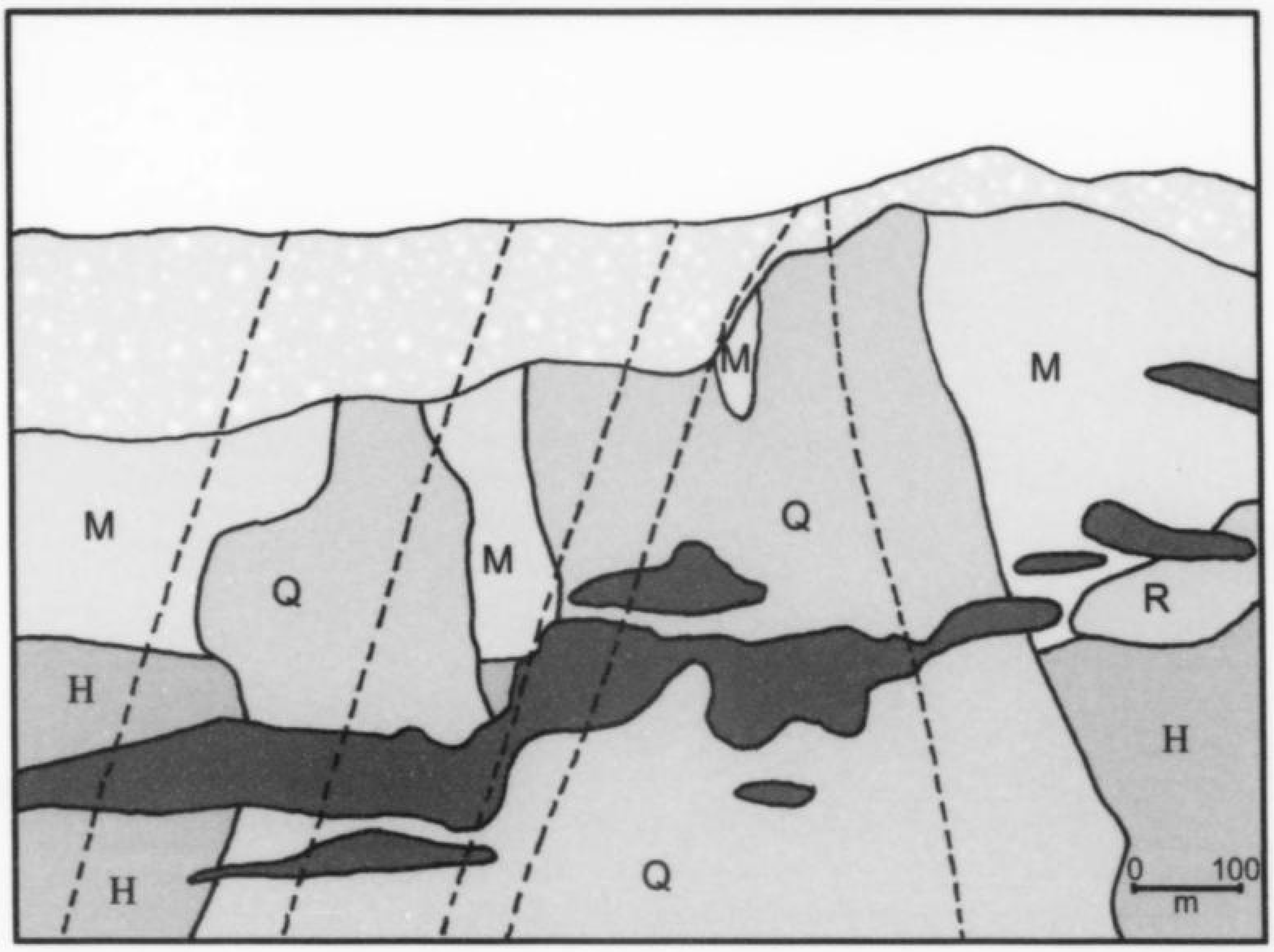

Figure 5. **Cross-sectional view of the Milpillas porphyry copper deposit.**

MINERALS

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

The best of the azurite specimens thus far found in the Milpillas mine approach the world's finest in quality and in sheer beauty, with lustrous, mirror-faced crystals of excellent dark blue color. The largest crystals seen by the authors reach 12 cm; Jones (2008) describes "the largest single [Milpillas azurite] crystal I've held in my hand . . . a stunning blocky crystal 4 inches long and more than 2 inches wide . . . [with] a brilliant luster." In nearly all cases, these large azurite crystals actually consist of azurite veneers overgrown on malachite pseudomorphs after earlier azurite crystals. Since the layer of second-generation azurite is thin, the crystals display a rich blue color—in contrast to the large, megascopically black crystals from Tsumeb, Namibia and the Touissit mine in Morocco. First-generation Milpillas azurite crystals without malachite cores have also been

Figure 6. **Azurite, 3.8 cm, from the Milpillas mine. Western Minerals specimen; Jeff Scovil photo.**

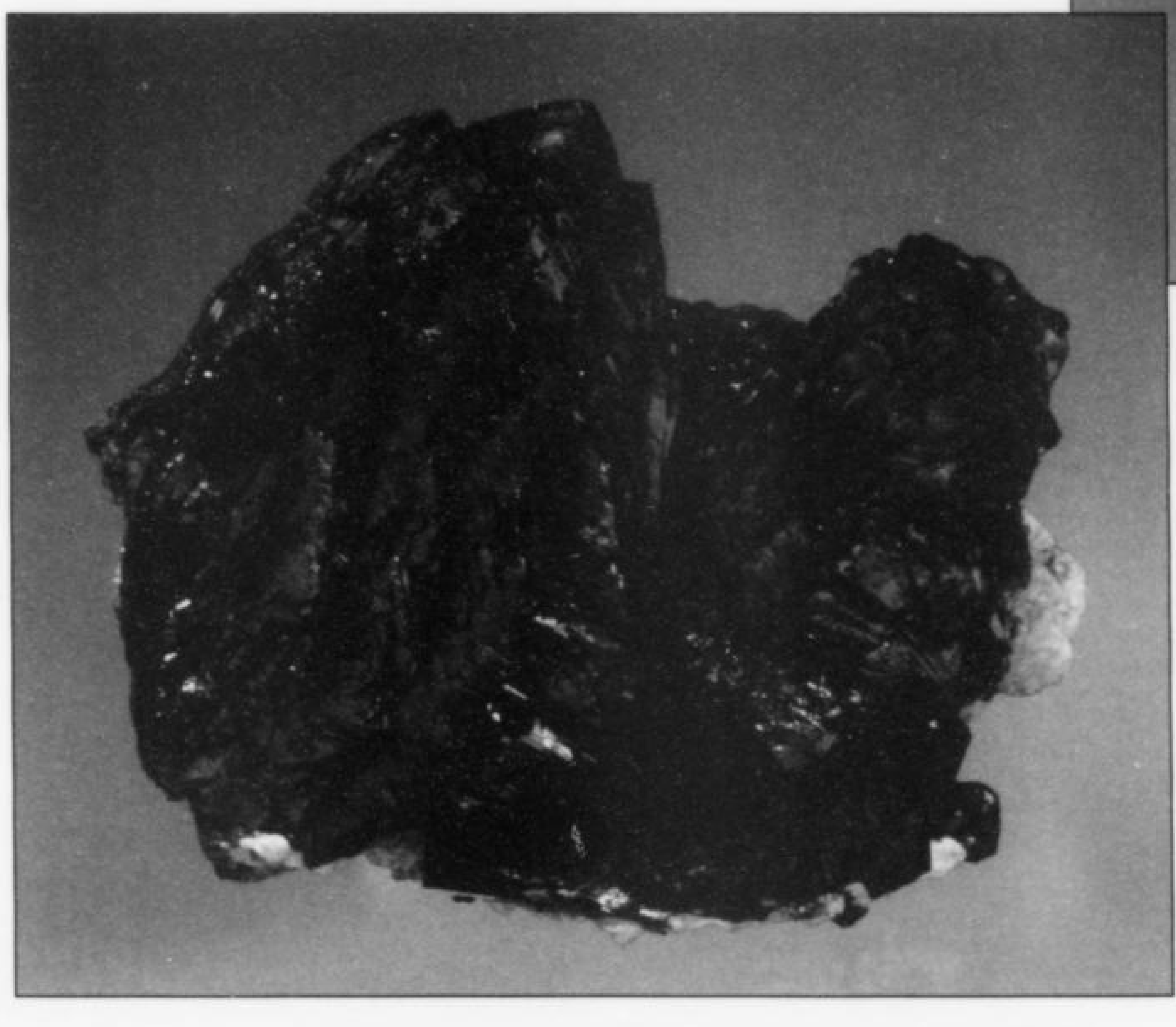

Figure 7. **Azurite, 5.4 cm, from the Milpillas mine. Western Minerals specimen; Jeff Scovil photo.**

Figure 8. **Azurite, 9.5 cm, from the Milpillas mine. Sandor Fuss specimen; Jeff Scovil photo.**

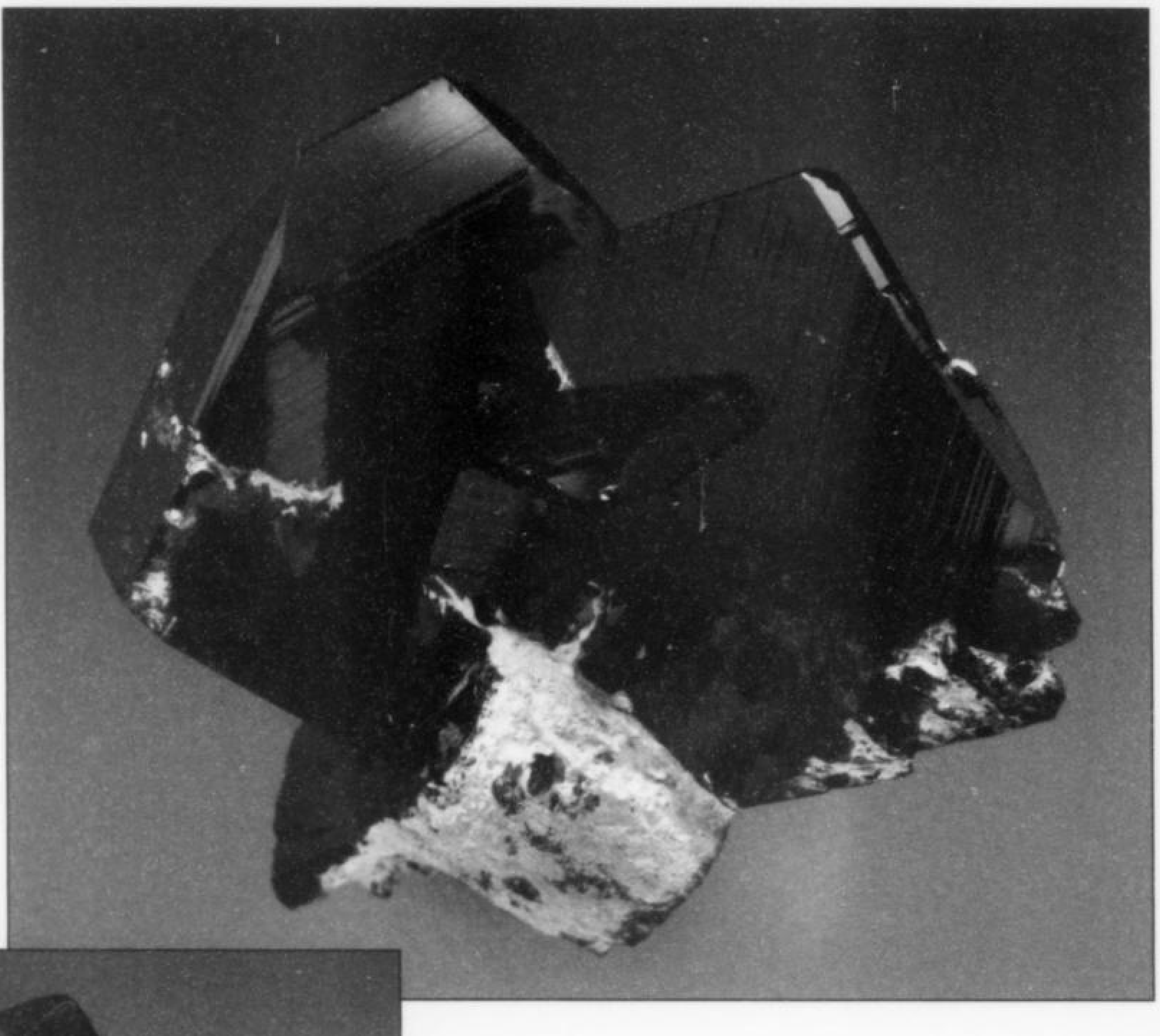

Figure 9. **Azurite, 3.8 cm, from the Milpillas mine. Frederic Escaut specimen via Fine Minerals International; Jeff Scovil photo.**

Figure 10. **Azurite, 6.6 cm, from the Milpillas mine. Western Minerals specimen; Jeff Scovil photo.**

seen by the authors: these approach a maximum size of 4 cm and, like their African counterparts, appear black or nearly so.

Some Milpillas azurite specimens show crystals diverging to form rose-shaped aggregates reaching several centimeters across, lying more or less flat on beautifully contrasting matrix of velvety dark green malachite; other specimens display stepped, dome-like clusters of lustrous blue crystals on malachite (Jones, 2008).

Azurite crystals occur in pockets and narrow seams (commonly filled with white, sticky clay) in brecciated rhyolite, mostly in the mine's upper levels. The crystals are commonly well individualized, even when they form solid linings on vug walls; however, the crystals may span the voids, causing contacts on multiple sides. Unfortunately, a large majority of the Milpillas mine azurite specimens so far seen show significant damage, either suffered in the course of ore-blasting or inflicted by hasty and/or inexpert collecting by miners. Some specimens which have reached the market are miniature-size crystal clusters; others are vug sections or crystal-covered matrix plates to cabinet size.

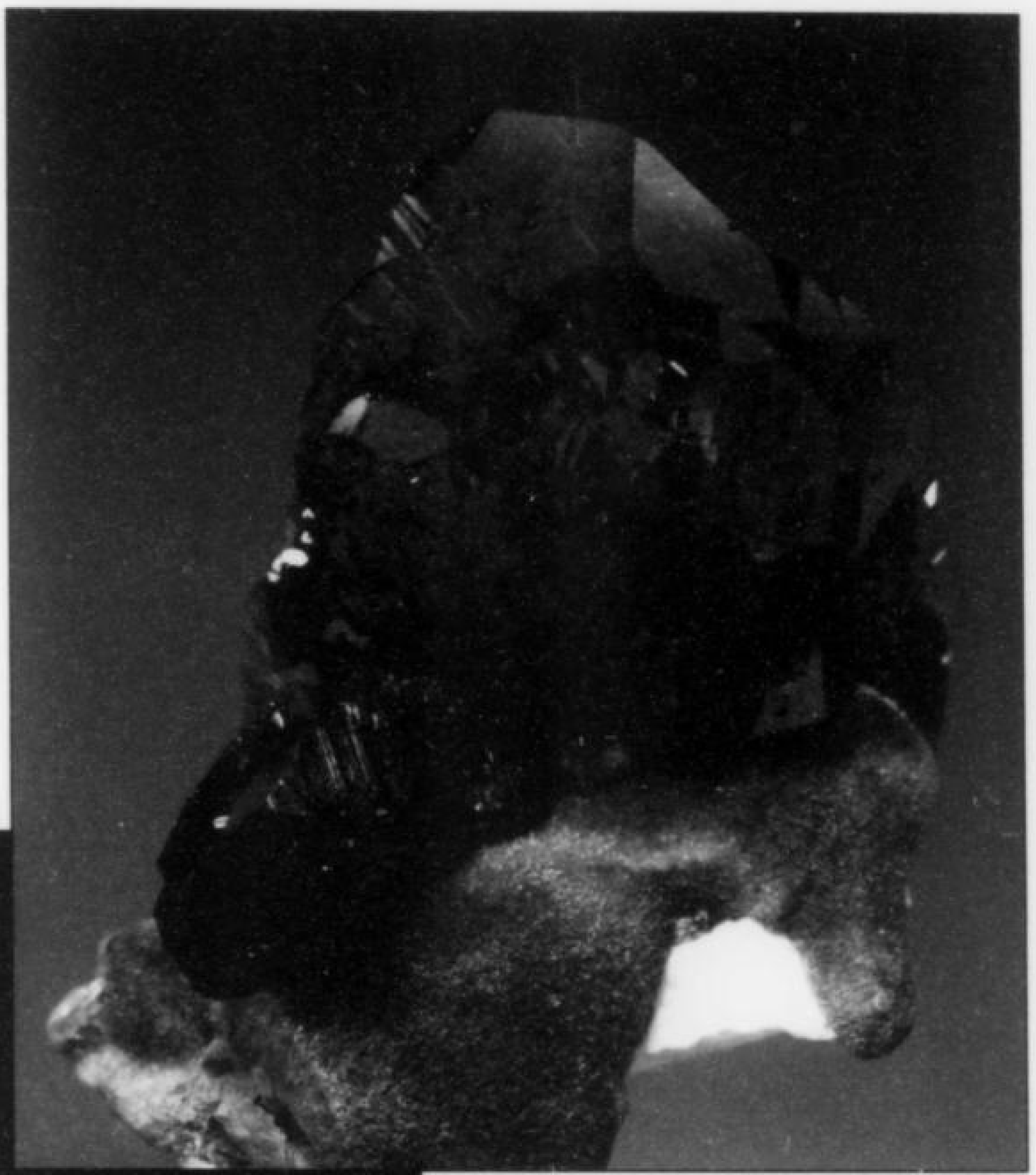

Figure 11. **Azurite, 5 cm, from the Milpillas mine. Joe Kielbaso collection; Jeff Scovil photo.**

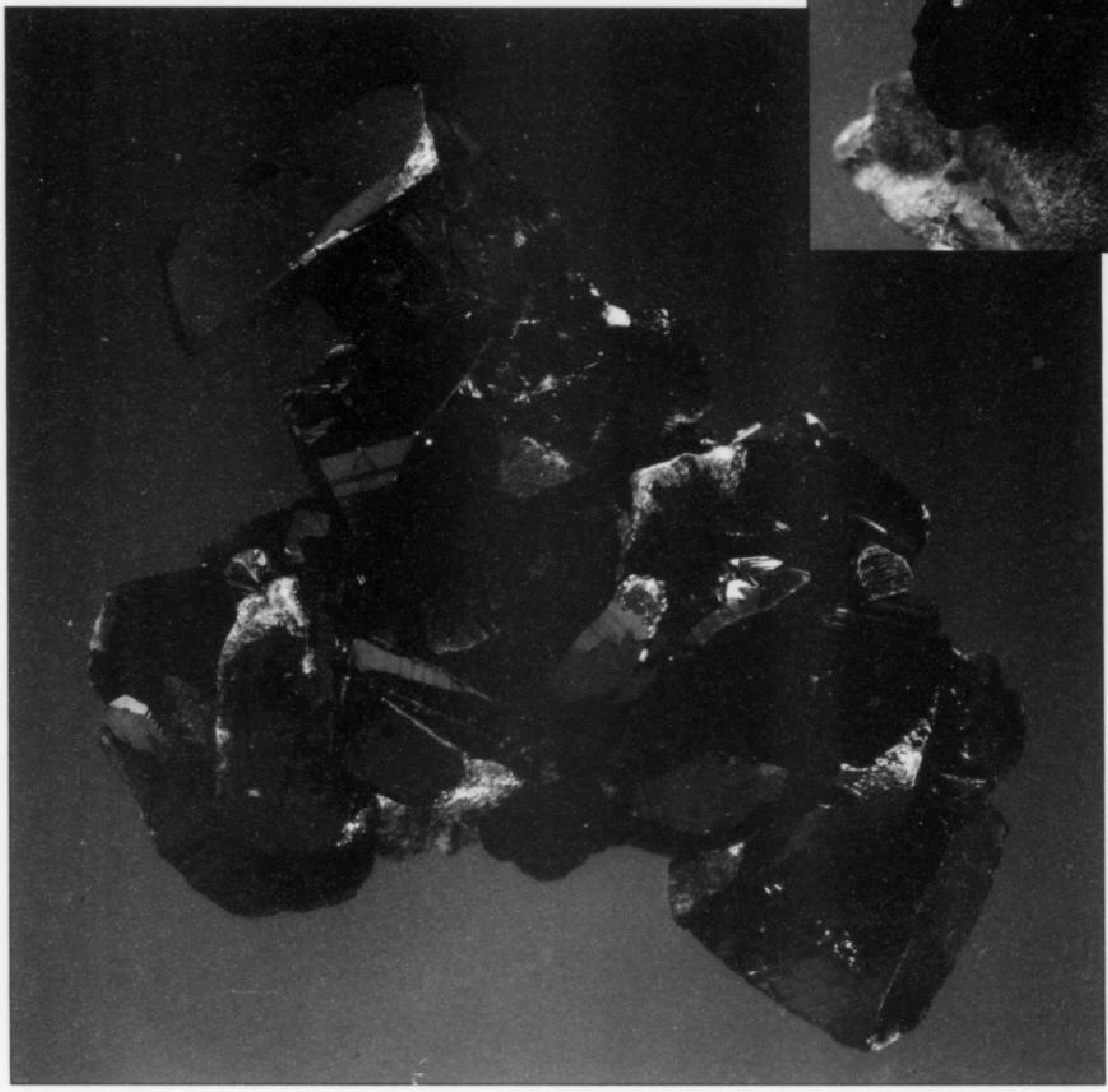

Figure 12. **Azurite, 7.5 cm, from the Milpillas mine. Rob Lavinsky specimen (ex Sandor Fuss) and photo.**

Although pockets of azurite crystals are apparently relatively common in the rhyolite stockworks, collecting by miners is intermittent, sporadic, and necessarily furtive. Good specimens nevertheless began to emerge not long after mining began; e.g. in October 2006 five flats of azurite crystals were taken from a pocket zone in a 5 to 12-cm-wide vein, and successfully smuggled out (Gene Schlepp, personal communication, 2007). Some of the earliest Milpillas specimens were falsely attributed to the long-famous locality of Concepción del Oro, Zacatecas (Jones, 2008).

Barite $BaSO_4$

At the Tucson Show in 2008, Phoenix mineral dealer Evan Jones had a single barite specimen from the Milpillas mine, and reported having seen a small handful of others. The marketed specimen shows thin-tabular, lustrous, transparent, pale yellow barite crystals to 5 mm in an open seam in weathered malachite/plancheite.

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

Brochantite is found as deep green, lustrous, prismatic crystals to 1 cm long lining seams and vugs in massive cuprite/chrysocolla.

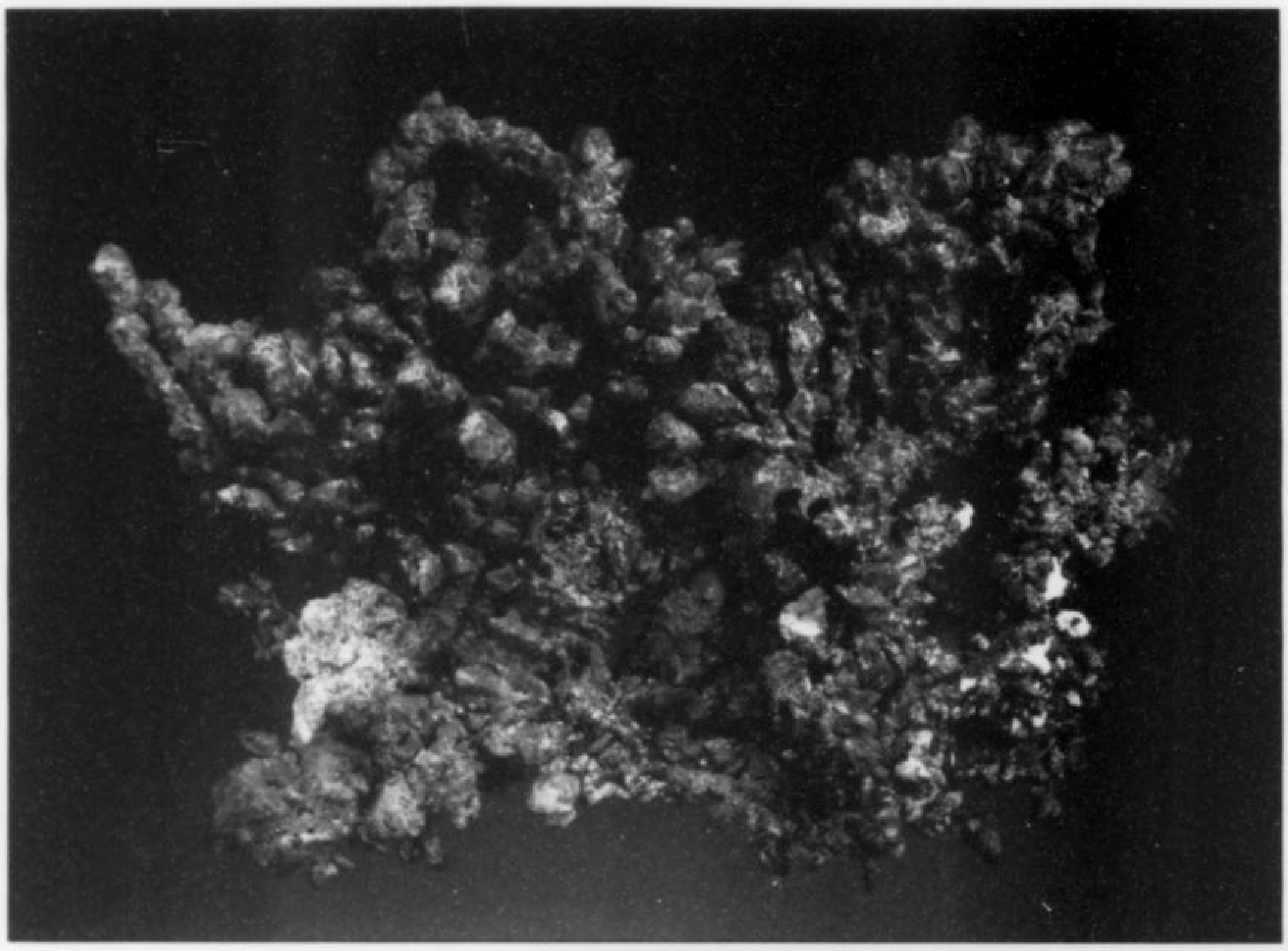

Figure 13. **Copper, 6.6 cm, from the Milpillas mine. Western Minerals specimen; Jeff Scovil photo.**

Figure 14. **Malachite pseudomorphs after azurite, 6 cm, from the Milpillas mine. Arkenstone specimen; Jeff Scovil photo.**

Figure 15. **Malachite pseudomorphs after azurite, 3.5 cm, from the Milpillas mine. Peter Megaw collection; Jeff Scovil photo.**

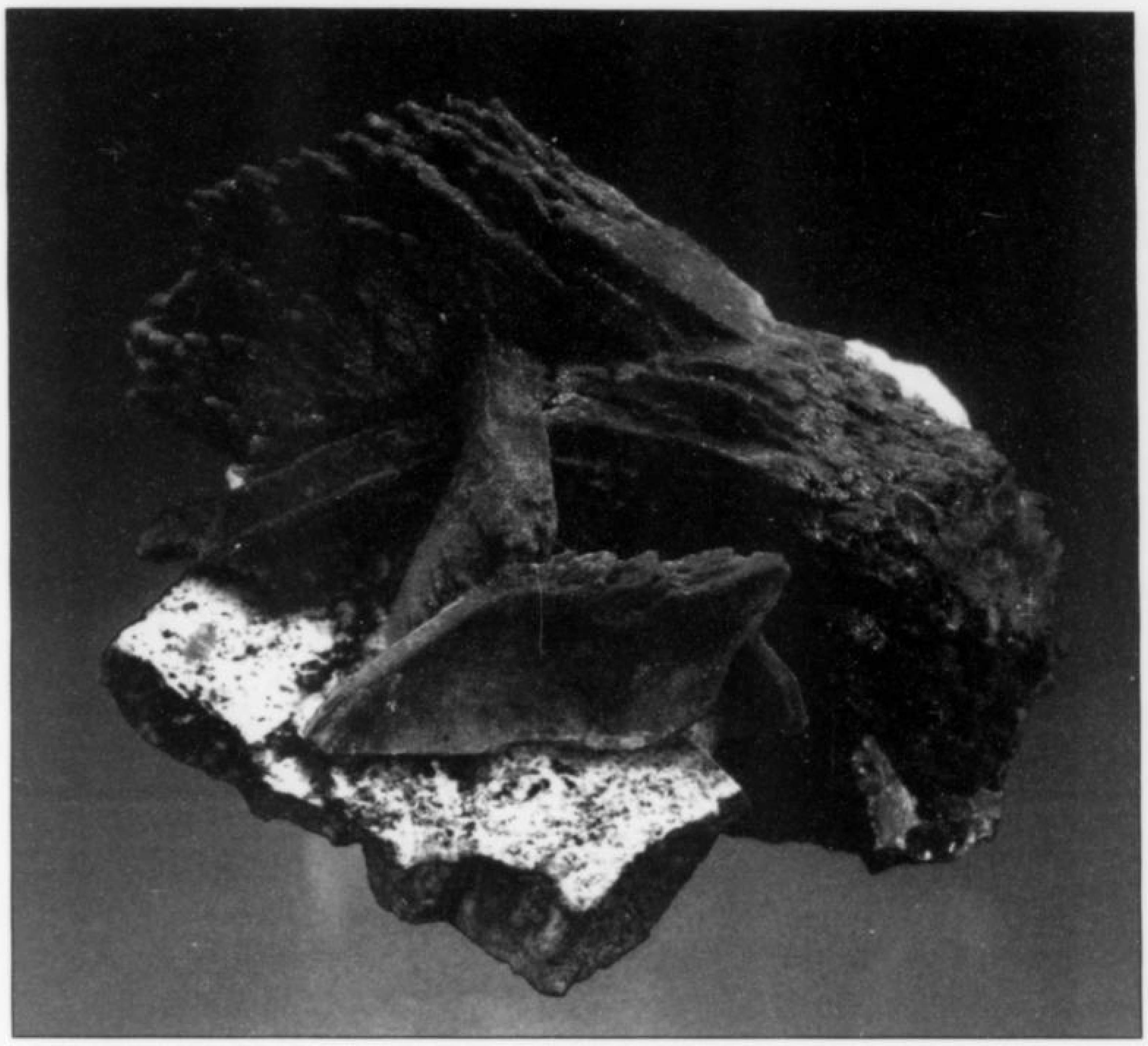

Table 1. **Mineral species reported from the Milpillas deposit.**

	De la Garza et al. (2003)	*This study*
Azurite	X	X
Barite		X
Brochantite	X	X
Chalcocite	X	X
Chalcanthite	X	
Chrysocolla	X	X
Copper	X	X
Covellite	X	
Cuprite	X	X
Delafossite	X	
Malachite	X	X
Neotocite	X	
Plancheite		X
Tenorite ("melaconite")	X	X

Chalcocite Cu_2S

Chalcocite is an important ore species at the Milpillas mine, especially in the lower levels (see under Geology and Mineralization). The authors have not seen free-standing crystals.

Chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$

Chrysocolla is common in the disseminated porphyry copper mineralization, occurring abundantly on the mine's upper levels as thick, dense, blue-green veins to several centimeters thick. Commonly the blue-green chrysocolla is speckled or veined with dull black (tenorite) or red (cuprite) alteration minerals. Purely blue-green or streaky blue/red (chrysocolla/cuprite) masses, being dense and fairly hard, have considerable potential as lapidary material. Jones (2008) writes:

> [Such material] can be cut and polished into brilliant, multi-colored cabochons of high luster exhibiting a random mix of red and blue. This quite gorgeous rock is coming out of the mine in large chunks, some of which are almost too heavy to lift. It has the lapidary world afire with excitement.

Copper Cu

Arizona mineral dealers Gene Schlepp and Evan Jones have handled several attractive copper specimens from Milpillas: lacy, arborescent aggregates to 20 cm consisting of rounded individual crystals to 1 cm, with some pale green staining by malachite and with minor attached clay. Some of the copper crystals are twinned on the spinel law. These copper specimens came from a single pocket discovery in late summer 2006 (Gene Schlepp, personal communication, 2007).

Cuprite Cu_2O

Massive cuprite forms veins in larger chrysocolla masses (see above under Chrysocolla). In a few observed specimens, blood-red, lustrous microcrystals of cuprite form druses lining cavities in the massive material (Evan Jones, personal communication, 2008).

Malachite $Cu_2^{2+}(CO_3)(OH)_2$

Two types of malachite occur at the Milpillas mine: "primary," i.e. non-pseudomorphous, malachite, and malachite pseudomorphs after azurite crystals. Hand specimens typically show only one of these types; only rarely do they occur in combination. Primary malachite forms small acicular crystals and massive coatings. Underground, the authors observed plumose malachite growths in vertical seams, which disintegrated when touched. Dense, radiating aggregates of acicular malachite crystals form delicate, rolling, velvety surfaces over rhyolite matrix, making for very attractive specimens. Jones (2008) observed that many "velvet malachite" specimens are slightly concave, as the crystal-lined pockets were small. Near the attachment points of the malachite encrustations with the altered volcanic matrix, blue spots of plancheite are often seen.

Clusters of malachite pseudomorphs after azurite commonly appear as floaters, with little attached matrix. The habit of the pseudocrystals varies considerably. A distinctive blocky type with a rectangular cross section and serrated edges is known; other examples preserve the forms of truncated, blocky azurite crystals. The surfaces of the malachite pseudomorphs sometimes show a velvet-like texture, and shimmer in moving light. The best pseudomorphous malachite specimens seen so far are floater groups and matrix pieces not exceeding 7 cm, and many of the pseudocrystals are "tipped" where their terminations touched the opposite wall of the seam or vug (Jones, 2008).

Superb Milpillas mine specimens of malachite pseudomorphs after azurite were first seen on the mineral market at the September 2007 Denver Show (as were the first significant Milpillas azurite specimens), and hundreds more appeared at the following Tucson Show in February 2008. In summer 2008 a Texas dealer, Rob Lavinsky (The Arkenstone), acquired about 30 miniature to large cabinet-size pseudomorphous malachite specimens from a pocket zone which was breached in mid-June 2008. These highly aesthetic specimens consist of very sharp, bladed pseudocrystals to 2.5 cm

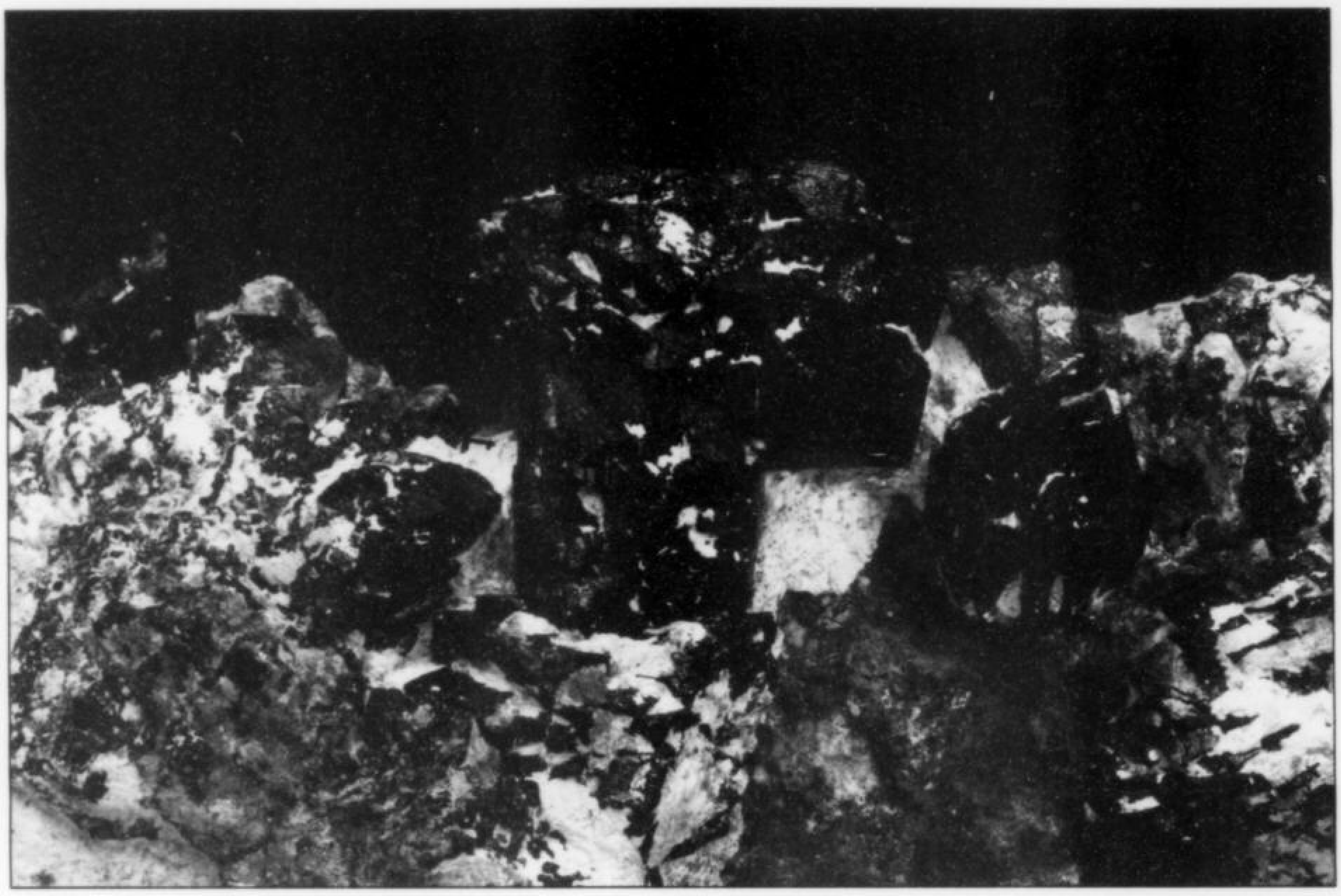

***Figure 16.* Azurite with blue plancheite and blue-green chrysocolla, 6 cm, from the Milpillas mine. Lavinsky collection; Jeff Scovil photo.**

forming mostly low-relief clusters, some with small bits of matrix, to 18 cm across. The malachite surfaces are forest-green with a shimmering luster.

Plancheite $Cu_8(Si_4O_{11})_2(OH)_4{\cdot}H_2O$

Plancheite occurs with primary malachite, typically in pale blue coatings and thin crusts. One spectacular pocket produced specimens showing acicular baby-blue plancheite crystals forming delicate tufts and seam-lining blankets. A discovery in late 2007 produced several specimens with tufts of pale blue plancheite in combination with felted velvet-green malachite: a large example, measuring about 20 × 25 cm, now resides in the Arizona-Sonora Desert Museum collection. Powder X-ray diffraction studies at the University of Arizona have confirmed the identification of plancheite. Masses of compact plancheite and malachite have afforded attractive polished gems.

CONCLUSION

Since their first market appearance late in 2006, the azurite and pseudomorphous malachite specimens from the Milpillas mine have become well-known to mineral collectors, and a fair number of dealers have secured supplies. The occurrence is already widely considered to be a "contemporary classic."

The Milpillas ore deposit is large and its exploitation is only beginning, so it is possible that specimens will continue to emerge sporadically for the next few years. However, the difficulties inherent in collecting, preserving and transporting specimens from the mine are significant, and there is no guarantee that productive zones will continue to be penetrated as mining progresses. Each good lot that emerges could be the last. Mineral collectors would be well advised to secure as soon as possible the best specimens they can from this remarkable, world-class occurrence of crystallized copper carbonates.

ACKNOWLEDGMENTS

We thank Dr. Robert Downs of the Geosciences Department of the University of Arizona for organizing our visit to the mine; the management and crew of the Peñoles Company, who were so courteous to us at the time of our visit; Salvador Ortiz and Francisco Quintana of the Peñoles Company for the location photography; and Jeff Scovil for the specimen photography. We are also grateful to Evan Jones, Peter Megaw, Rob Lavinsky, Mike New, Wendell Wilson and Gene Schlepp for information and helpful discussions.

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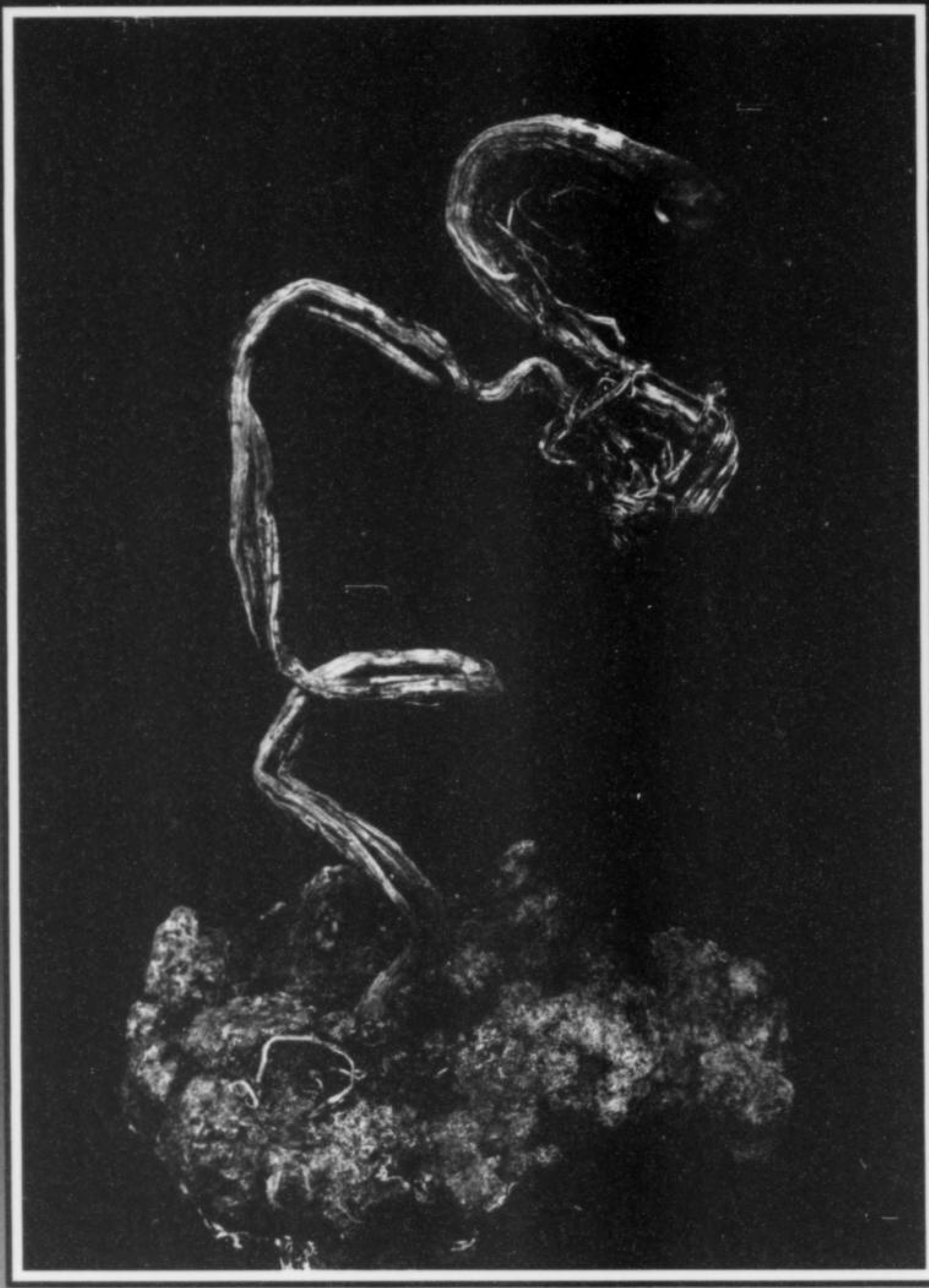

SILVER - 9 CM - RUSSIA

Famous Mineral Localities:

The Las Chispas Mine

Arizpe, Sonora, Mexico

Terry C. Wallace
5040 Hermosura
Los Alamos, New Mexico 87544

In the first decade of the 20th century, the Las Chispas mine near Arizpe in Sonora produced some of Mexico's largest and best specimens of polybasite crystals, large clusters of "poker chip" stephanite crystals, fine acanthite crystal clusters and a few very fine pyrargyrite specimens. Most of these were saved through the enlightened efforts of mine manager Edward L. Dufourcq (1870–1919).

INTRODUCTION

In 1904, Edward L. Dufourcq, a graduate of the Columbia School of Mines, took over the management of the Las Chispas mine near Arizpe (Arispe) in Sonora, Mexico, a modest mining property owned by the Minas Pedrazzini Gold and Silver Mining Company. Soon he began shipping some extraordinary silver mineral specimens back to New York, including the largest and best polybasite specimens known, large clusters of "poker chip" stephanite crystals, fine acanthite specimens and a few very fine pyrargyrite specimens. These were sent to various institutions, but mainly to his alma mater. Dufourcq described some of the material he sent to New York in an article published in 1910 in *The Engineering and Mining Journal:*

> The crystallized specimens of the silver minerals are especially noteworthy . . . What is probably the largest single specimen of stephanite in the world was presented by Mr. Pedrazzini to the Egleston Collection at the Columbia School of Mines, where there are also a number of other specimens of polybasite and stephanite, as well as a remarkable specimen representing the transition of an argentite crystal into cerargyrite and a fine embolite. The American Museum of National History in New York also has, from this mine (the Las Chispas), what is probably the largest mass of polybasite crystals ever taken out in one piece. This originally weighed over 65 lb., but was broken into two parts during the time it was in transit from Sonora to New York (Dufourcq, 1910).

Today many museums and private collections have spectacular examples of Arizpe silver minerals. It is probable that the Las Chispas mine produced no more than 20 million ounces of silver, but because Dufourcq took special care to preserve a suite of mineral specimens, Las Chispas must be considered a classic mineral locality.

HISTORY

Early in the 17th century, Jesuit priests began to enter the rugged basin-and-range desert country that is modern-day Sonora. The Jesuits' intent was to convert the indigenous populations to Christianity, but their missionary settlements also opened the region for Spanish miners and ranchers. In 1640, soldiers under the command of Pedro de Perra discovered a system of veins rich in silver in the Valley of the Rio Sonora, near the future town of Arizpe (West, 1993). Although the exact location of this discovery is lost to recorded history, the descriptions are consistent with the future Las Chispas

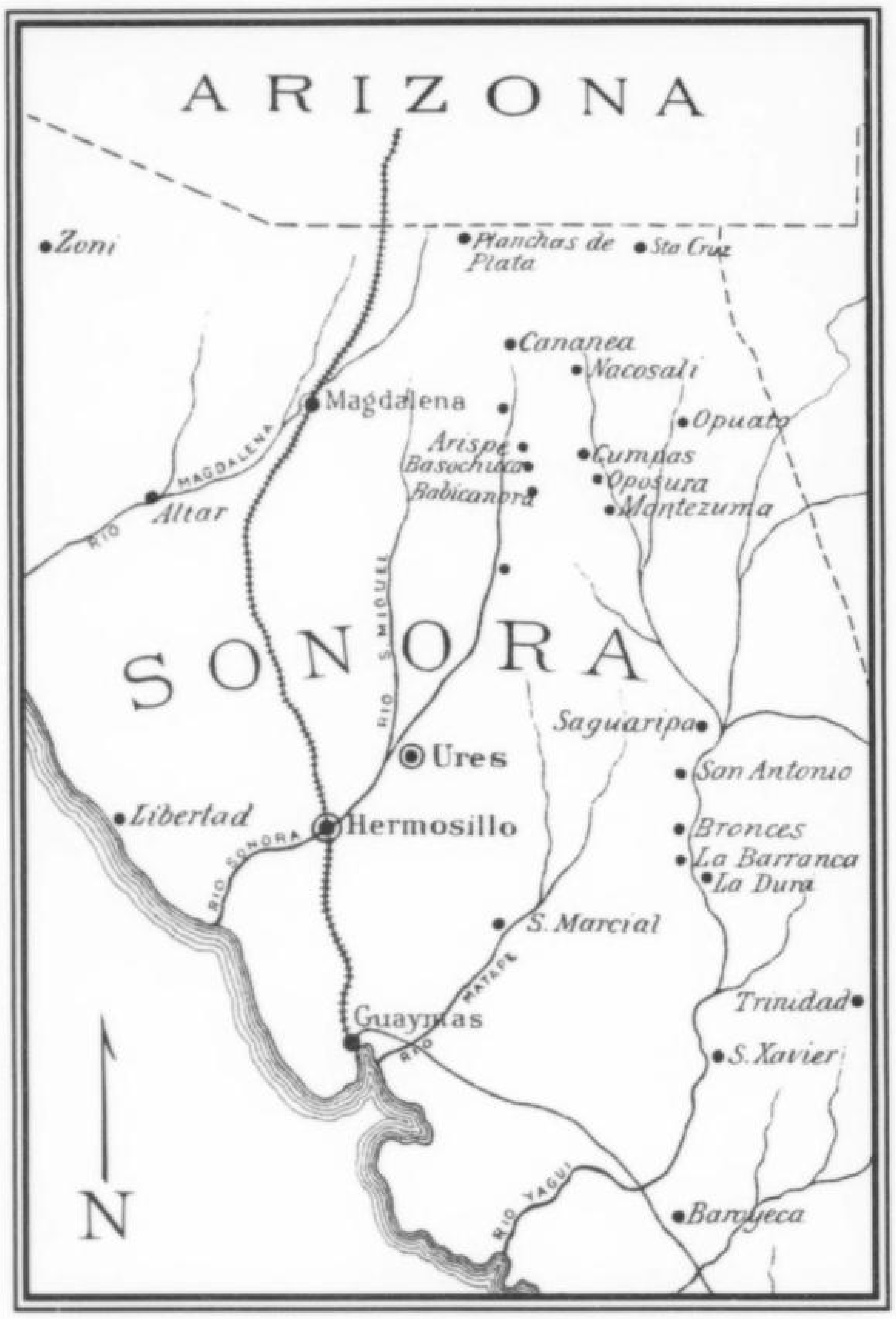

Figure 1. **Location map (adapted from Dahlgren, 1883). The Las Chispas mine is actually located south of Arizpe, closer to Babiconora (Bavicanora).**

mine and adjacent Bavicanora mine. There was no documentation of organized exploitation of this original Sonoran silver discovery, but there was extensive exploration of the surrounding area. Jesuit missionary Jeronimo de la Canal established the town of Arizpe in 1646. The name "Arizpe" is a word from the language of the Opatas (the indigenous inhabitants of the Rio Sonora Valley) meaning "place of the fierce ant." The original church, Nuestra Señora de la Asunçión Temple, constructed in the year of the town's founding, is still standing today. Arizpe became a major administrative center in 1776 when it was proclaimed the capital of the Provincias Internal de Occidente, which included Sonora, Durango, Chihuahua, Arizona, California and Sinaloa. Arizpe fell from grace after the Mexican Revolution, and today is a town of approximately 2,000 inhabitants.

In 1657, rich silver ore was discovered about 40 km south of the original Arizpe discovery, at a site called San Juan Bautista, in the mountains between the Rio Sonora and the Moctezuma Valley. San Juan Bautista became one of the largest silver producers in Sonora during the latter 17th century, and was made the administrative capital of the region. Colonial records give an idea of the mining wealth: in the first two years of operation, miners produced more than 4,000 pounds of refined silver from shallow workings. Almost certainly the ore was chlorargyrite and some minor native silver. By 1680, silver mining had all but ceased at San Juan Bautista, and the miners had moved on to other strikes at Nacozari, Bacanuchi and, most importantly, Alamos. The story of the San Juan Bautista is typical of the early mines of Sonora: subsistence mining, shallow workings, little record of the mine's passing, and few tangible remains except for abandoned mine buildings and ore-processing patios.

After the first 50 years of exploration and colonization, the mountainous regions of Sonora entered a long period of economic decline that was marked by nearly continuous confrontation with Apache and Seri nomads. The first documented Apache raid on a Spanish outpost occurred in 1680, and the raids continued for the next 200 years, forcing the abandonment of outlying communities and mines. The Spanish government organized several military expeditions against the raiding tribes. The expeditions were primarily funded by the mining enterprises and wealthy ranchers, but the peace won by these expeditions was always short-lived until a combined Mexican and American military force finally defeated Geronimo in 1880.

With the Indian threat removed, a renaissance in Sonoran mining took place. Political stability came with the dictatorship of Porfirio Diaz, and during his reign (1877–1911) Mexico welcomed investment in the nation's mining industry. Foreign companies explored extensively in Sonora and reopened many of the old abandoned mines (called *antiguas).* Around 1880 the Las Chispas mine is first mentioned in the records. Russell (1908) states: "During the early eighties the Santa Maria Mining Company was operating a small gold-silver prospect a few miles south of Arizpe in the northern part of Sonora, Mexico." The mining operation suffered from poor management and apparently lost considerable ore to highgraders. Eventually the Santa Maria Mining Company went bankrupt, and left the close-out of its business to the company clerk, an Italian-Swiss named John Pedrazzini. Pedrazzini acquired the property in lieu of money owed him by the company, and he set about raising capital to reopen the mine. In 1893 the Pedrazzini Corporation provided a special exhibit in The World's Columbian Exposition in Chicago that is reported to have contained some spectacular specimens of silver minerals (Lejeune, 1908).

Figure 2. **The mission church of Nuestra Señora de la Asunçión in Arizpe, built in 1646.**

Figure 3. **Stock certificate for the Minas Pedrazzini Gold and Silver Mining Company (1924). Mineralogical Record Library collection.**

As Pedrazzini raised capital he began extensive exploration work which included a tunnel driven into the hill about 125 meters. This adit intersected the Las Chispas vein at a depth of about 185 meters below the surface outcrop, and the real production history of the Las Chispas (also called the Pedrazzini) mine began. In 1904, E. L. Dufourcq was hired as the general manager and consulting engineer; shortly thereafter, Pedrazzini incorporated his holding into the Pedrazzini Gold and Silver Mining Company. Dufourcq rapidly developed the mine, and built a modern 20-stamp mill and cyanide processing plant. By early 1910 the Pedrazzini Company employed approximately 600 men, almost 500 working in the Las Chispas mine (Dinsmore, 1911). For the years 1907–1911 the Las Chispas mine produced an average of 1.5 million ounces of silver and 10,000 to 12,000 ounces of gold.

Even during the most productive times, ore theft at the Las Chispas mine was a problem. Russell (1908) relates a tale illustrating the extremes to which miners and speculators would go in order to get rich quick: a Cananea ore-purchasing company attempted to secretly purchase high-grade Las Chispas ore, and ended up with tons of specular hematite from a nearby mine.

Between 1911 and 1921 the Las Chispas mine suffered the ravages of the Mexican civil war. The war interrupted transportation, and in general caused considerable labor unrest. In 1917 the mine was confiscated by the local government, which highgraded the mine and mill and expropriated much of the mine infrastructure. The local government also renegotiated a labor contract with the miners which was quite unfavorable to the operation of a profitable mine. Eventually the mine was returned to the Pedrazzini Company, but it took several years of developmental work before the mine could produce ore again. Around 1918 a large flood destroyed the pump station for the mill along the Rio Sonora, and thereafter the mill was limited to using water pumped from within the mine (Montijo, 1920).

In 1921 the Corporation Miniere du Mexique was formed in Paris with a 25 million franc capitalization with the intent of purchasing the Pedrazzini workings. Through a Mexican subsidiary, the Corporación Minera de Mexico, S.A., the French took over the mine, remodeled the power plant and began a profitable eight-year run at the Las Chispas mine. In 1924 the company struck a bonanza vein, and the next year it paid a 25 % dividend (Berstein, 1964). By 1930, however, the mine had ceased organized operation.

In the 1960s the mine was visited by a number of mineral collectors who recovered some fine stephanite specimens. The late Arizona mineral collector Joseph Urban told a story of his visit to the mine: he had thought that it was abandoned, and so was very surprised to find that people were actually living in the mine openings. He sketched in the dirt a hexagonal shape to indicate what he was looking for; one of the local men understood, went into the mine and came out with a handful of hexagonal polybasite crystals (Wayne Thompson, personal communication).

In the 1970s the mill and mine tailings were hauled away for concentration, and most of the old mine buildings were removed.

GEOLOGY

Arizpe is located in eastern Sonora, in the physiographic province known as La Serrana. The area is composed of north-south-trending fault-bounded mountain blocks separated by south-flowing river drainages. La Serrana forms the southernmost extension of the Basin and Range Province. The first geologic map of the area was published in 1888 by José Guadalupe Aguilera Serrano, who described the region as a "gigantic staircase" between the Sierra Madre Occidental in the east and the lowlands in the west bordering

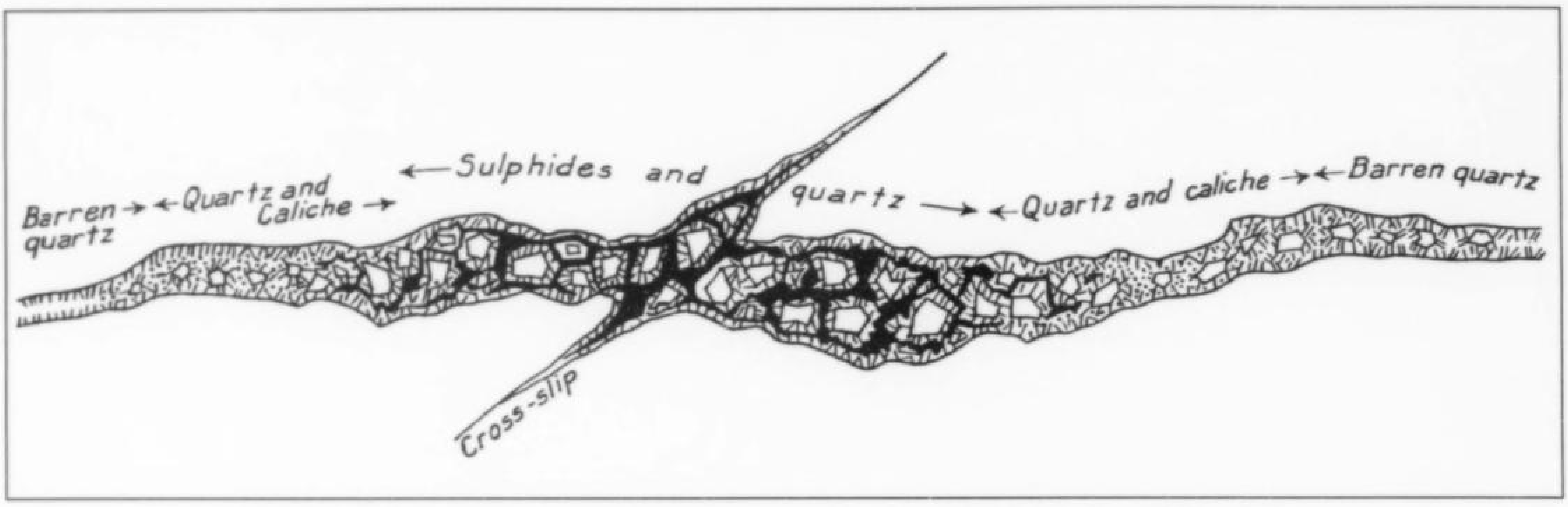

***Figure 4.* Horizontal cross-section through a typical ore pocket in the Las Chispas mine. The fissure area contains a breccia of wall rock (white) coated by quartz (hatched) and in-filled with silver minerals (black) (from Montijo, 1920).**

the Gulf of California. The mountain ranges are largely composed of Laramide-age flows and tuffs of intermediate composition, which were intruded by a series of subvolcanic stocks (Valencia-Moreno *et al.*, 2007). These stocks are the source of mineralization exploited in the Las Chispas and surrounding mines.

The Las Chispas vein is one of a series of northwest-southeast trending fault-fissure mineralized zones. Other major veins include the Guillermo Tell, the Carmen, and the Bavicanora (located about 1 km east of the Las Chispas). All of these veins have produced significant quantities of silver. The Bavicanora is thought by some to have been the source of the original silver discovery in 1647 (Box, 1869), and is credited with producing at least 80 million ounces of silver (Woodbridge, 1911).

The Las Chispas vein is hosted by a felsic porphyry and overlying rhyolite. The vein is primarily quartz with metallic mineralization consisting of pyrite, silver sulfides and sulfosalts, and occasionally chalcopyrite. Silver mineralization within the vein shows strong secondary enrichment; ore minerals grade from chlorargyrite and silver at the top of the vein to pyrargyrite at depth. In the wider sections of the vein, open vugs several feet across were common, and this is where the large crystals were found. Russell (1908) wrote:

> The ore occurrence is chiefly remarkable for the extreme richness and beauty of the high-grade *chispas**, or crystals of silver, from which the most fully developed property—Las Chispas—takes its name. This ore occurs in boulders, stringers and lenses in a series of 14 nearly parallel fissure veins in the rhyolite. The vein filling is a rhyolite breccia carrying the [silver] values in the cracks and seams, which vary from the merest crack to 2 feet or even 3 feet in thickness. The stringers of ore extend so far [into the walls] as to render it necessary to carry the stopes from 12 feet to 18 feet in width for considerable distances.

The vein system is very antimony-rich, and arsenic appears to be largely absent. Figure 4 from Montijo (1920) is a stylized cross-section through the vein, showing the ore concentrated in irregularly spaced pockets.

The prevalence of bonanza-type pockets along the veins in the Las Chispas mine makes it difficult to infer the quality of the ore that was shipped to the mill. Outside the pockets the vein rarely exceeded 10 ounces of silver per ton, but within the pockets the ore averages more than 2,000 ounces per ton (Dinsmore, 1911). The individual pockets have distinctive ore mineralogy, but the bulk of the mineralization consists of acanthite, polybasite and stephanite. It is very common for acanthite and silver specimens to have a matrix of polybasite. The only other mineral of interest to collectors is fluorite. Many of the polybasite specimens have an overgrowth of pale-colored fluorite, which is very distinctive and diagnostic for the locality.

*Literally "The Sparkles," miners' slang for "The Crystals."

MINERALS

The annual report of the American Museum of Natural History records many donations from Dufourcq. For example, in 1907 it is noted that Dufourcq gave "8 specimens of Argentite (all crystallized and one very unusual); 2 specimens of Polybasite with wire Silver; 8 specimens of Stephanite (crystallized), from Las Chispas mine, Arizpe, Sonora, Mexico." These specimens are exemplars of some truly magnificent silver sulfides and sulfosalts from Arizpe, and are among the finest known from anywhere in the world.

Acanthite Ag_2S

Acanthite is the most common of the ore minerals at Las Chispas, and the best examples rank among the world's finest for the species. At Arizpe acanthite comes in two different habits: blocky

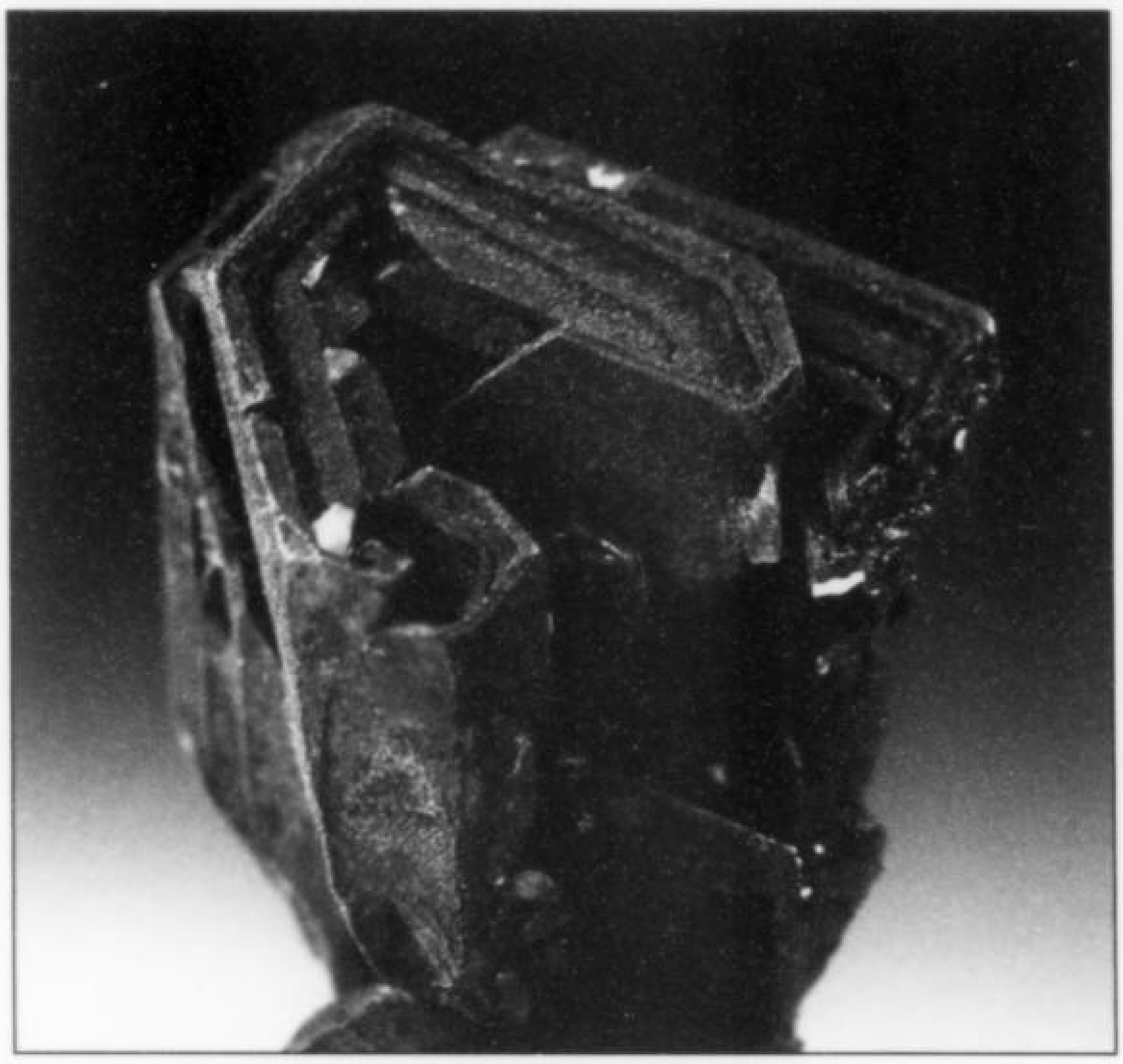

***Figure 5.* Acanthite thumbnail crystal, 2.3 cm, from the Las Chispas mine. It was originally part of the famous collection of George Vaux (1863–1927). In 1958, 31 years after his death, it was presented along with the rest of his collection to Bryn Mawr college. Terry Wallace collection; Wendell Wilson photo.**

Figure 6. **Acanthite crystal cluster from the Las Chispas mine, 11.4 cm. It was collected by John Pedrazzini, who presented it to mineralogist Eduard Schmitter, who in turn presented it to his young protégé, Miguel Romero. Considered perhaps the finest example of the species, it is now in a private collection in Paris; Wendell Wilson photo; Arkenstone specimen, now in a private collection.**

Figure 7. **Acanthite crystal cluster, 4.4 cm, from the Las Chispas mine. Collector's Edge Minerals specimen (ex Mel and Grace Dyck collection); Richard Jackson photo.**

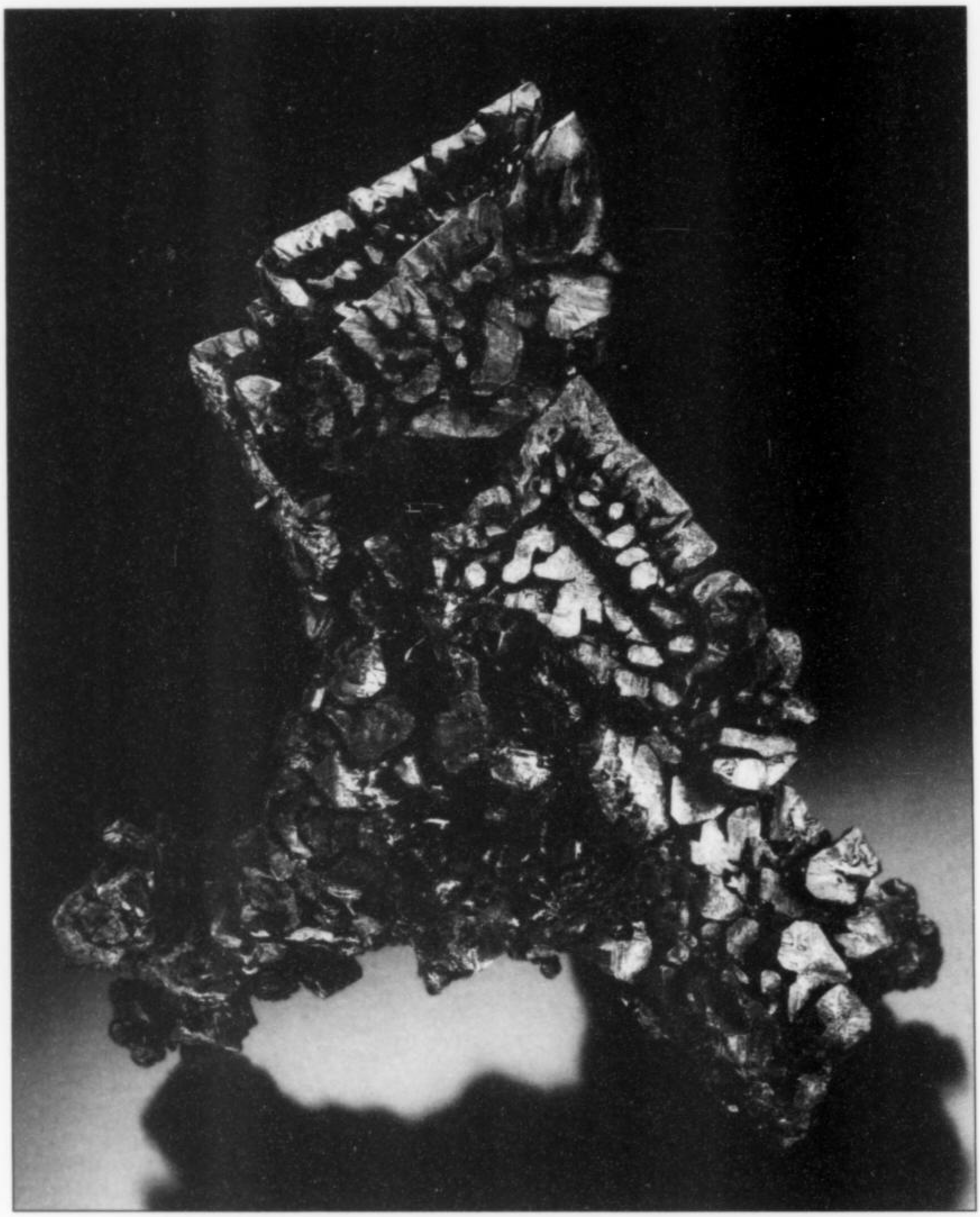

Figure 8. **Acanthite crystal cluster, 9.3 cm, from the Las Chispas mine. Houston Museum of Natural Science collection; Jeff Scovil photo.**

cubes to 4 cm, and elongated skeletal prisms. The blocky crystals often have a drusy coating of pyrite, and commonly appear to be parasitic growths on polybasite. The elongated prisms are unique to Las Chispas, and typically form clusters of crystals. The finest example known is a specimen that passed from Pedrazzini to Eduard Schmitter to Miguel Romero.

Fluorite CaF_2

Many of the polybasite specimens from Arizpe are partially covered with small, highly modified fluorite crystals. Desautels (1960) described the fluorite, noting that a unique feature of Las Chispas fluorite is that each crystal shows seven forms of the hexoctahedral class. Figure 10 shows a typical Las Chispas crystal. Forms present are the cube (*a*), octahedron (*o*), dodecahedron (*d*), tetrahexahedron (*e*) {012}, trapezohedron (*m*) {113}, trisoctahedron (*q*) {133}, and hexoctahedron (*t*) {124}. The faces of {012} and {111} are always etched. The cube, dodecahedron and trapezohedron are about equally dominant, and the other forms are of lesser importance.

Polybasite $[(Ag_8CuS_4)][(AgCu)_6(Sb,As)_2S_7]$

Polybasite is found in the Las Chispas mine as short pseudohexagonal prisms and as hexagonal tablets. Some of the prisms reach 12 cm across. Many of the polybasite specimens from Arizpe are associated with small, complex, nearly clear, crystals of fluorite which coat the edges of the polybasite crystals. The largest of the Arizpe polybasite crystals have thick tabular shapes, although perhaps the finest known specimen is a cluster of paper-thin crystals up to 8 cm across. This specimen was a gift from the Pedrazzini family to Dr. Eduardo Schmitter, Mexico's dean of mineralogy. Schmitter stored the fragile specimen in a large coffee can filled with powdered soap. In the 1950s Dr. Miguel Romero Sanchez worked in Schmitter's lab as an undergraduate at the Universidad Nacional Automa de Mexico (UNAM), and Schmitter inspired a love of minerals in Romero. In the early 1970s, when Romero began to build the world's finest collection of Mexican minerals, Schmitter gave the polybasite to him.

Desautels (1960) described a polybasite specimen in the Smithsonian collection (no. R7867) weighing 37 kg (82 pounds); it consists of an open network of splendent crystals associated with complex fluorite crystals and crystals of pyrite, quartz and chalcopyrite.

Pearceite has been reported from the Las Chispas mine, but every specimen labeled "pearceite" which has been X-rayed by the author has proven to be polybasite. Hall (1967) included an analysis that showed the Arizpe polybasite to be dominated by antimony.

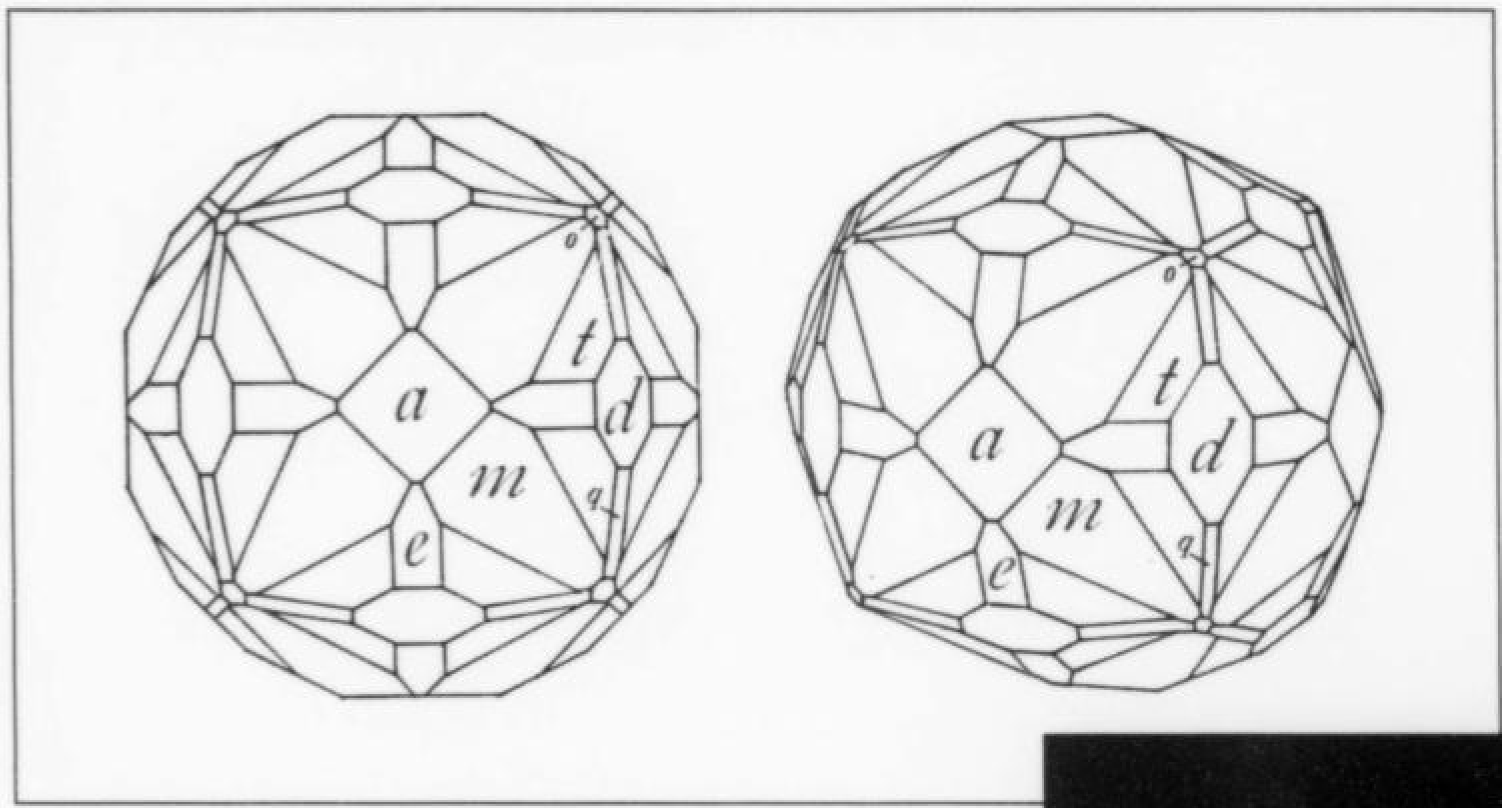

Figure 9. **Idealized crystal drawings (orthographic and clinographic projections) of fluorite from the Las Chispas mine (Desautels, 1960).**

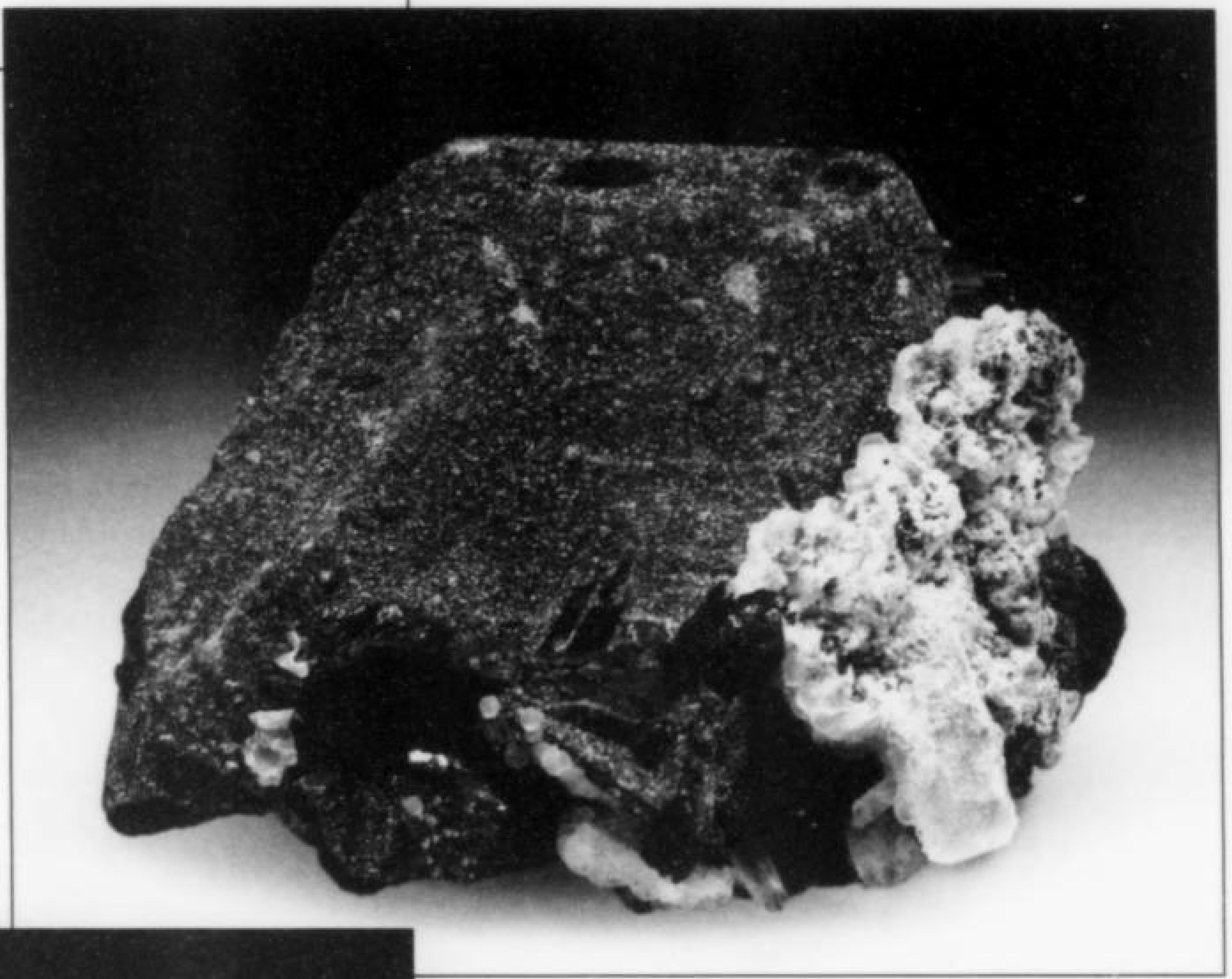

Figure 10. **Polybasite crystal with chalcopyrite coating, 5.4 cm, from the Las Chispas mine. Arizona-Sonora Desert Museum collection; Jeff Scovil photo.**

Figure 11. **Polybasite crystal with chalcopyrite, 3 cm, from the Las Chispas mine. Terry Wallace collection; Wendell Wilson photo.**

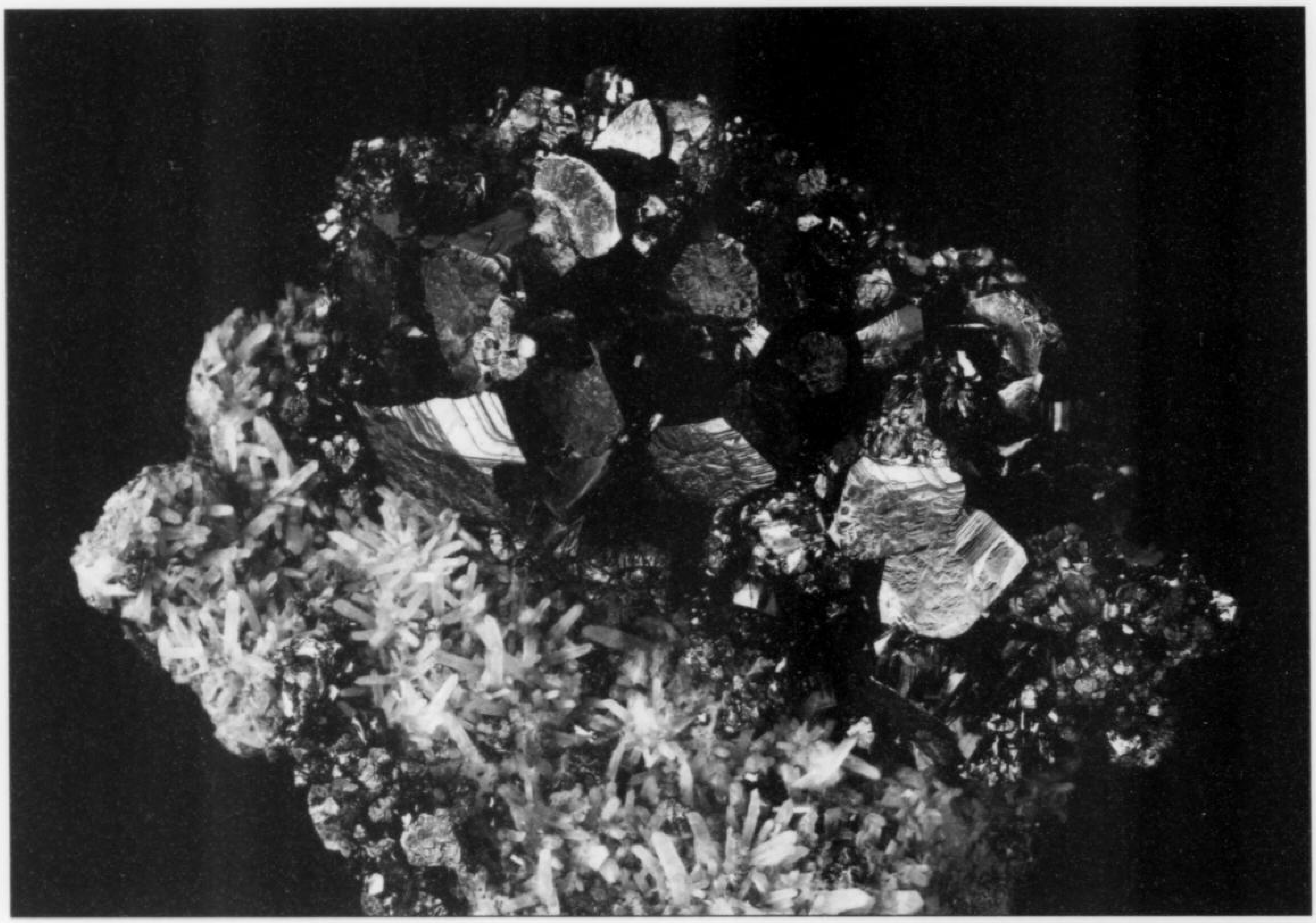

Figure 12. **Pyrargyrite crystal cluster on drusy quartz with chalcopyrite, 15.5 cm, from the Las Chispas mine. Wayne Thompson and Doug Wallace specimen now in a private collection; Jeff Scovil photo.**

Pyrargyrite Ag_3SbS_3

Pyrargyrite from Arizpe is uncommon in collections. However, there are a few truly outstanding examples with fine translucent red crystals to 5 cm which must be considered mineral masterpieces. Within the Las Chispas vein system the pyrargyrite was found in large pods devoid of other silver minerals.

Silver Ag

Native silver is widely reported from Arizpe, although examples are rare in museums. The silver typically occurs in bundles of wires associated with acanthite (the wires grow out of the acanthite). The wire bundles reach 7 cm in length and 3 cm across. An old Arizpe miner interviewed by Wayne Thompson in 1972 described seeing a walk-in vug festooned with stalactitic arborescent wire silver studded with dark crystals of silver sulfides.

Stephanite Ag_5SbS_4

Stephanite is one of the signature minerals from Arizpe. The best examples are extremely sharp pseudo-hexagonal "poker chips" that reach 5 cm across. Most stephanite crystals from the Las Chispas mine are short, thick, pseudo-hexagonal prisms formed by a combination of the prism and pinacoid, exceptionally to 12 cm across. This habit shows radial striations corresponding to twinning. A second, less common habit consists of elongated pseudo-hexagonal prisms, occasionally reaching 5 cm in length. Ford (1908) speculated that the two habits are related to different periods of formation. The pseudo-hexagonal prisms typically have a brilliant luster whereas the large "poker chips" are a dull black.

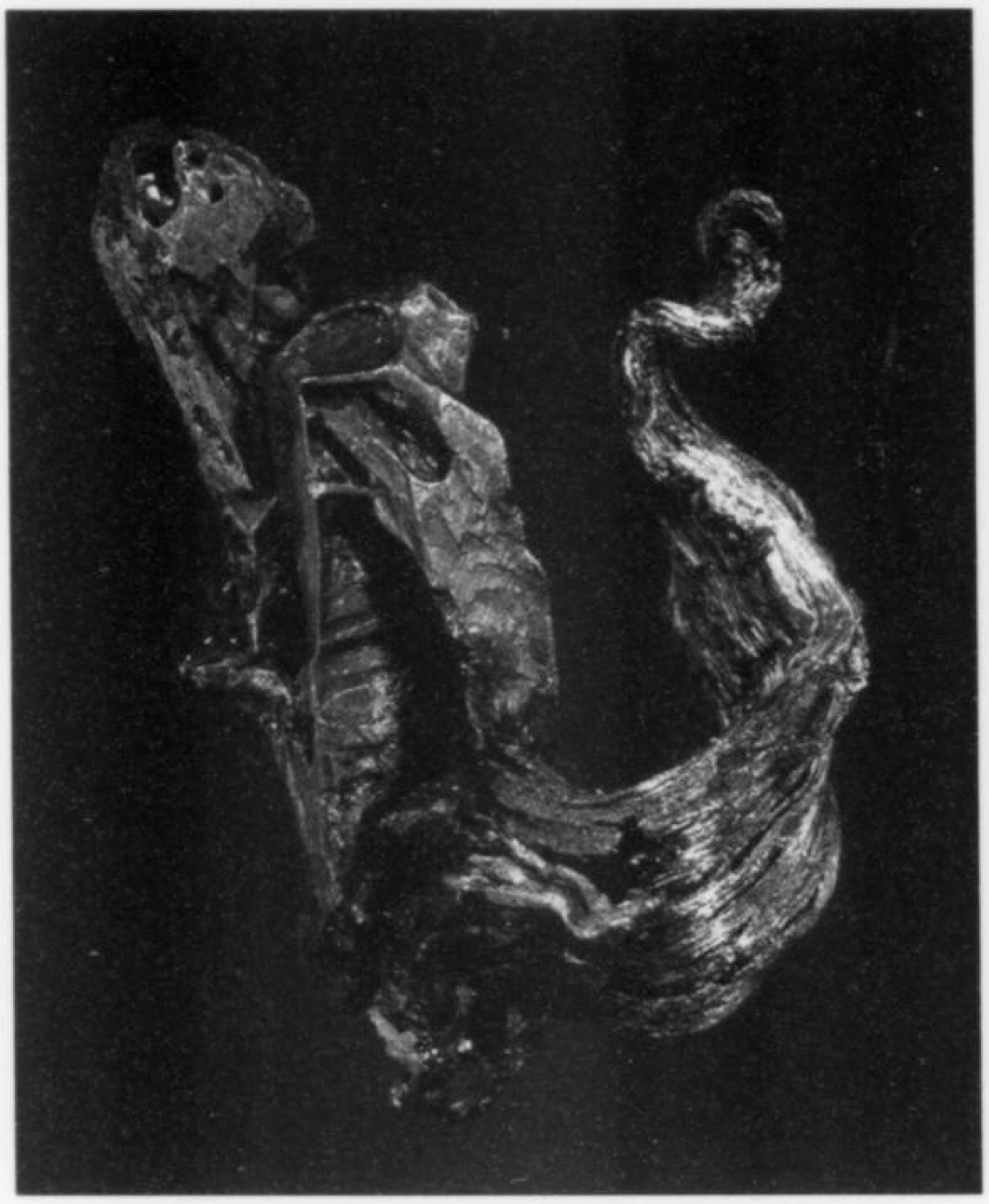

Figure 13. **Wire silver growing from acanthite crystals, 2.2 cm, from the Las Chispas mine. Ex James and Dawn Minette collection, now in the Terry Wallace collection; Jeff Scovil photo.**

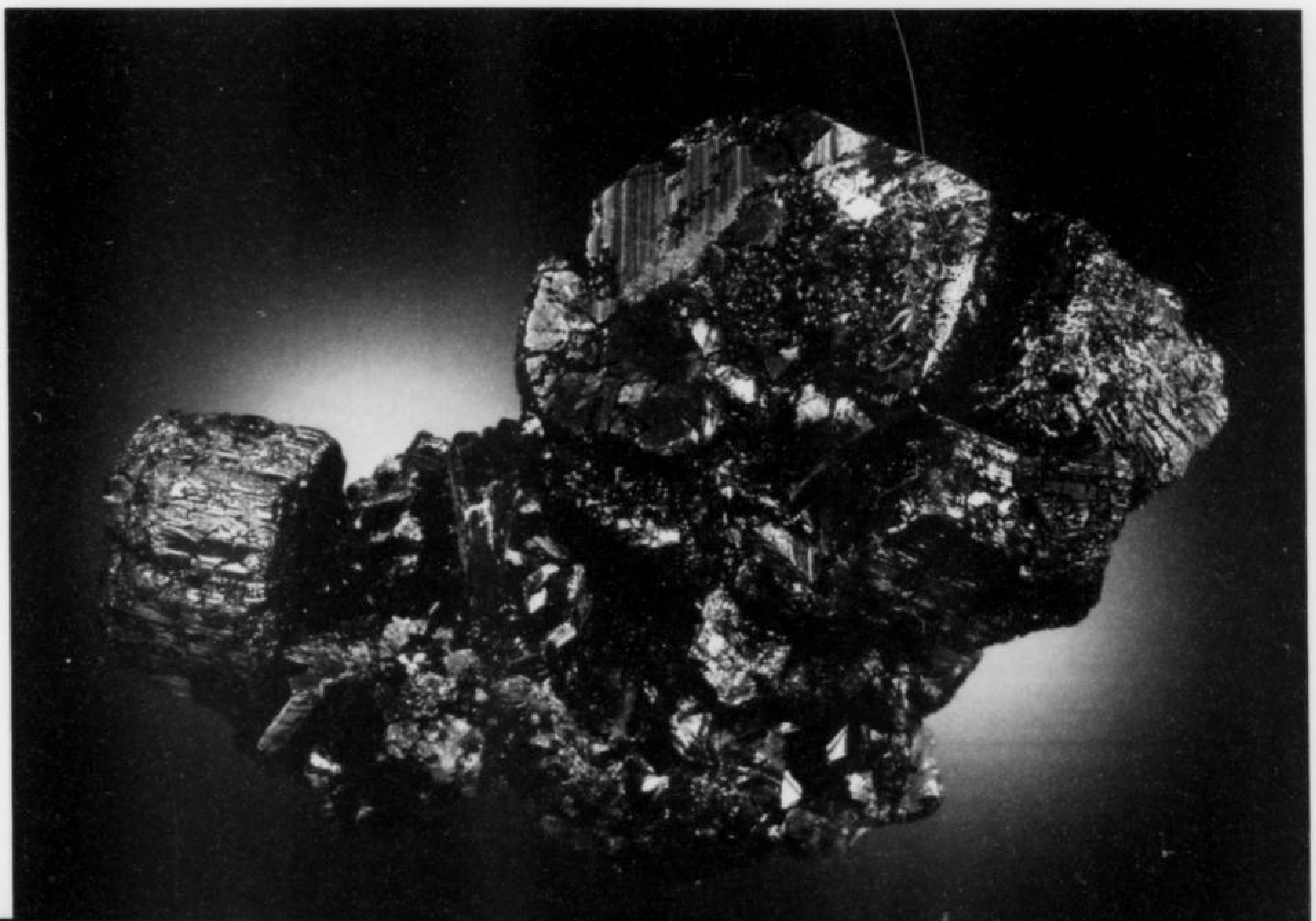

Figure 14. **Stephanite, 9.7 cm, from the Las Chispas mine. Rock Currier collection; Jeff Scovil photo.**

Figure 15. **Stephanite crystal cluster, 7.5 cm, from the Las Chispas mine. A. E. Seaman Mineral Museum, Michigan Technological University; John Jaszczak photo.**

Figure 16. **Stephanite, 3.2 cm, from the Las Chispas mine. Cal and Kerith Graeber collection; Jeff Scovil photo.**

CONCLUSIONS

The production history of the Las Chispas mine is mixed, since it was interrupted by revolution, strikes and seizure. The total silver production of the mine probably did not exceed 20 million ounces, but it must be considered one of the "classic" localities owing to its production of fine mineral specimens. The number of specimens now in museums and private collections is the legacy of a very enlightened mine manger, Edward L. Dufourcq.* Although Dufourcq

*Edward Leonce Dufourcq was born in New York on August 6, 1870, and graduated from the Columbia School of Mines in 1892.

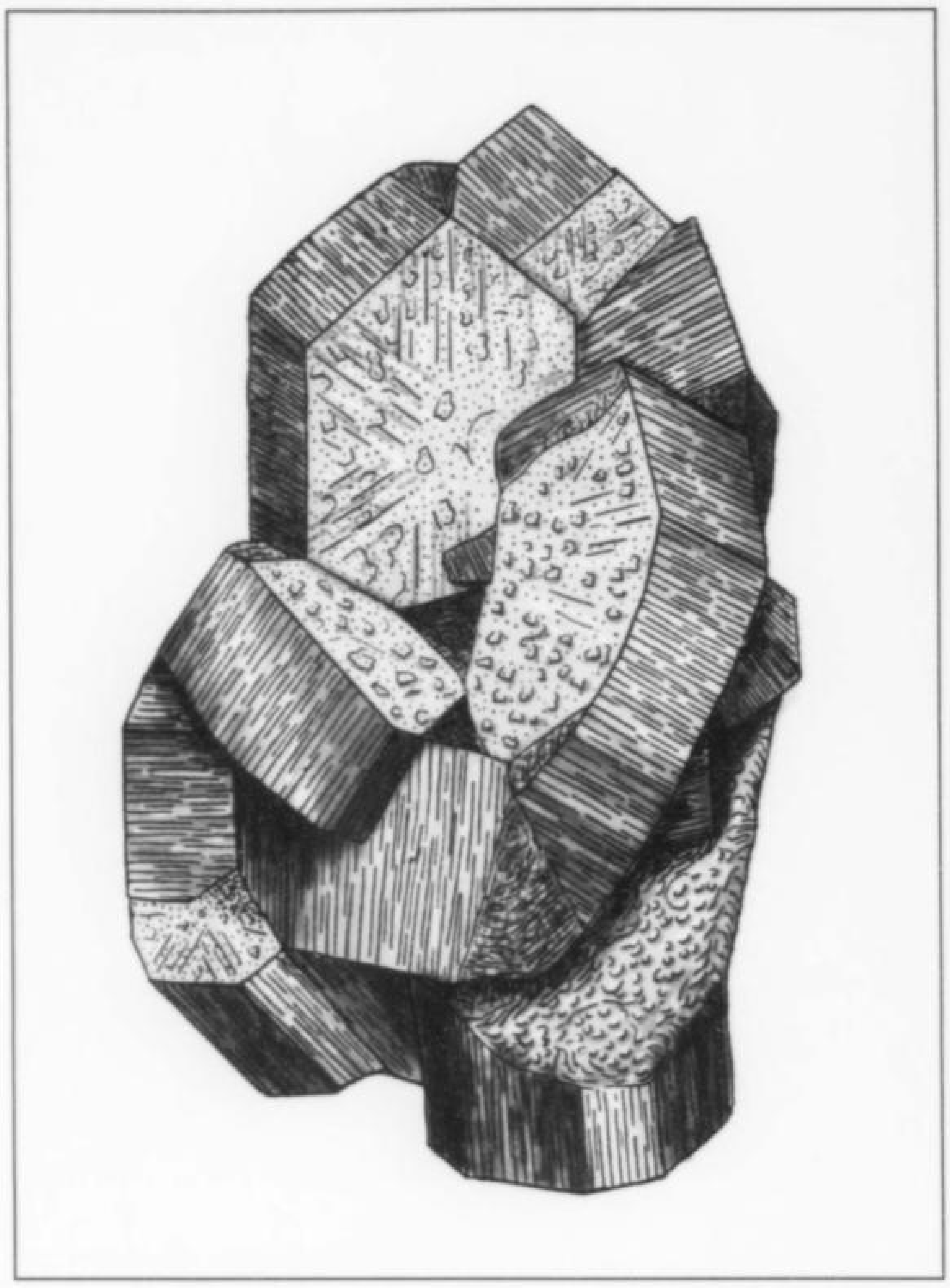

Figure 17. **Stephanite crystal cluster, 7.5 cm, collected by J. Pedrazzini at the Las Chispas mine; sketch by William E. Ford (1908a); shading added by Wendell Wilson.**

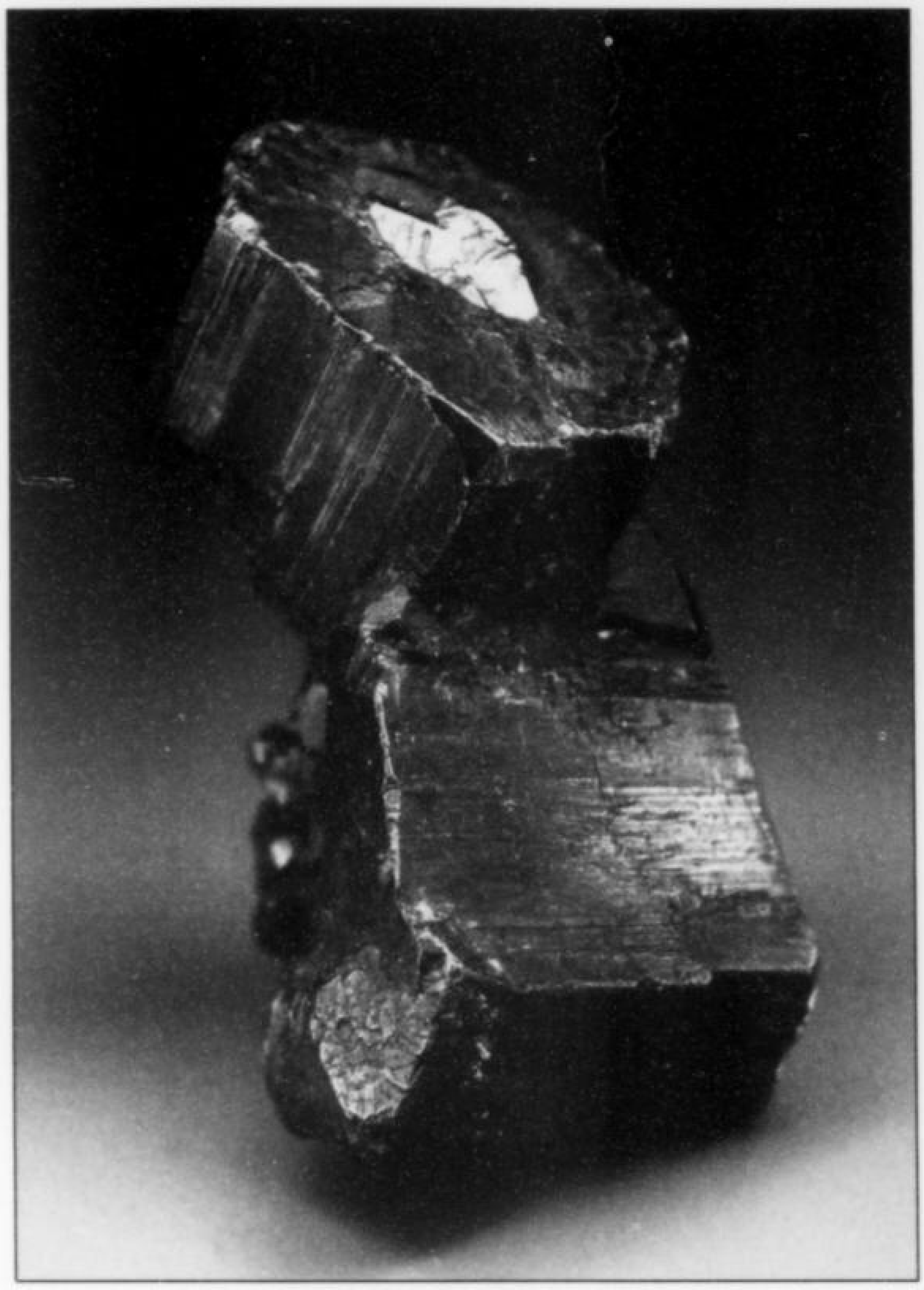

Figure 18. **Stephanite, 4.1 cm, from the Las Chispas mine. Arizona-Sonora Desert Museum collection; Jeff Scovil photo.**

struggled with constant highgrading and ore theft, he recognized that the specimens of acanthite, stephanite, polybasite and pyrargyrite were remarkable and worthy of preservation.

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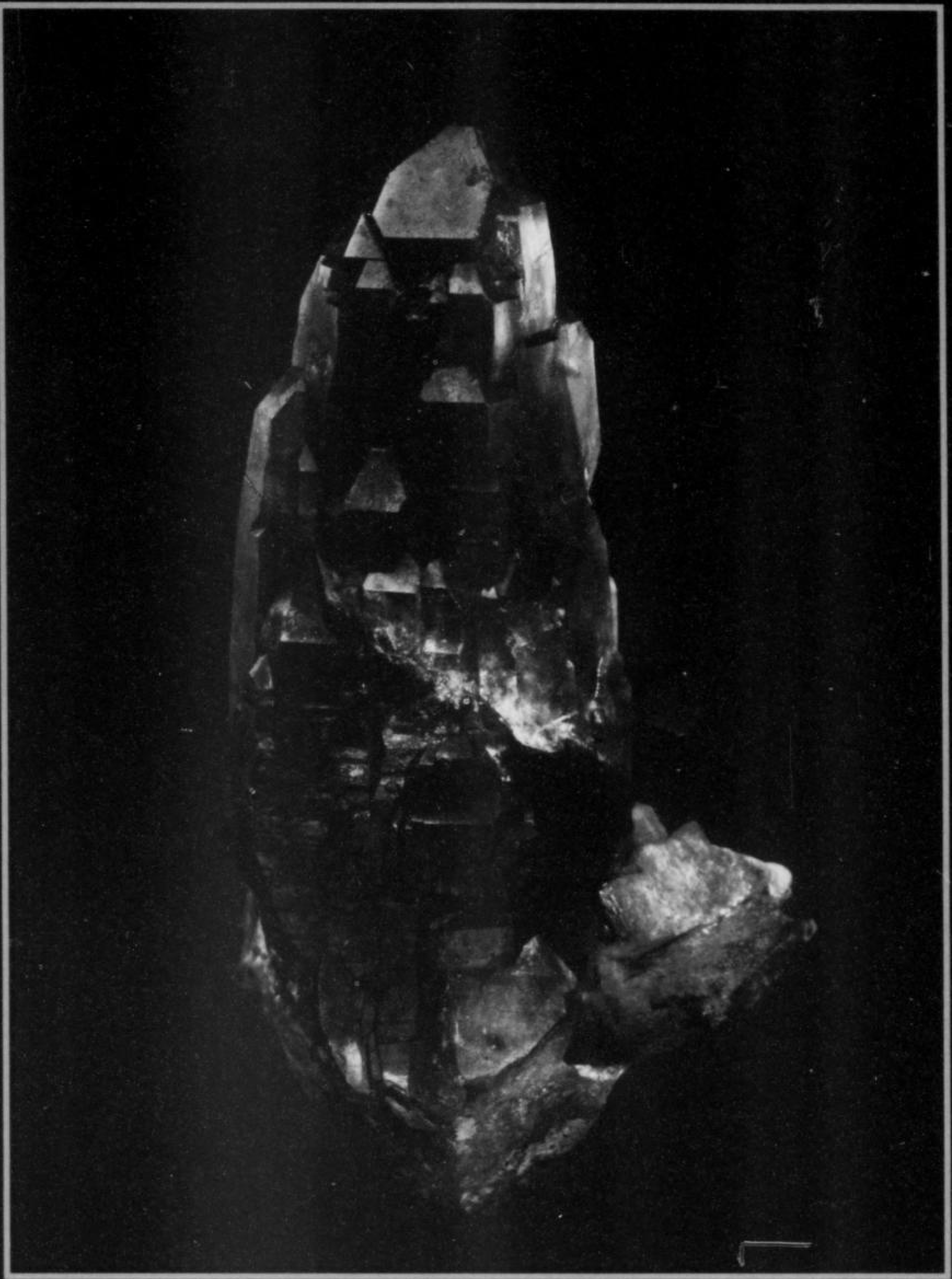
He worked for various American mining companies, mostly in Central America and Mexico, serving as mine superintendant at San Miguel de Mezquital, Mexico (1894–1896); at Sierra Mojada, Mexico (1896–1898); as manager of the Andes mine in Chimbote, Peru (1901); as general superintendant of the Montezuma Lead Company in Santa Barbara, Mexico (1901–1904); and as assistant general manager of the Tezeutlan copper mine in Mexico. He was waylaid and killed in Mexico by Zapatista revolutionaries on April 15, 1919 (Marquis, 1943; *Fort Worth Star-Telegram*, July 17, 1919).

Wisconsin



SMOKY QUARTZ, 10.1 cm, from the Bielke pit in the "rotten granite" (grus) within the Ninemile Pluton of the 1,460-million-year-old Wausau Syenite Complex near Wausau, Marathon County, Wisconsin. Purchased from Costigan's Minerals at the Green Bay Gem & Mineral Show, Neville Public Museum, Green Bay, Wisconsin, in April 2008. The specimen is from the collection of Walter Tamminen, who collected it in the late 1970s.

From the Shawn M. Carlson Collection

Famous Mineral Localities:

The Apex Mine

San Carlos, Chihuahua, Mexico

Thomas P. Moore
The Mineralogical Record
2709 East Exeter St.
Tucson, AZ 85716

The San Carlos replacement deposit of argentiferous galena, mined briefly in the late 19th century and again from ca. 1930 to 1952, has produced beautiful and distinctive vanadinite specimens, as well as a limited number of superb wulfenite specimens. Although situated quite close to the border with the United States, it is a relatively unknown locality seldom visited by field collectors.

LOCATION AND SETTING

The San Carlos replacement deposit of argentiferous galena lies in desert country in east-central Chihuahua, in the Municipio of Manuel Benavides, about 20 air-kilometers southwest of the international border at the Rio Grande and 60 km southeast of the point where the Conchos River joins the Rio Grande at the twin border towns of Ojinaga (Chihuahua) and Presidio (Texas). Because the orebody lies "like a saddle blanket" (Hewitt, 1970) across the top of an anticlinal ridge rising 300 meters above the surrounding plain, the lead mine which once operated there was called the Apex mine; however, in print sources as well as in collectors' casual discourse, it is much more frequently referred to as the San Carlos mine, after the nearby village of San Carlos.

Both along the ridge and below it, the much-faulted limestone terrain is very rough: a steep-walled *barranca* (ravine), raging with floodwater after rains, runs generally southeast from a precipitous drop-off near the mine site. Outcrops of magnetite skarn appear over a distance of more than 1 km along the barranca's walls, but lead and zinc sulfides are visible only at the northwestern end, near the mine. The village of San Carlos lies about 5 km from the base of the ridge, but otherwise the region today is largely uninhabited, quite as it was (except for mines) when the mine was last active, between ca. 1930 and 1952.

HISTORY

Newberry (1883) and Stetefeldt (1889) noted that by the late 19th century three shafts had already been sunk (by unspecified entities) along a line crossing the San Carlos orebody, all three lying within a lateral distance of about 100 meters. The Purissima shaft, 20 meters deep, had penetrated about a meter of ore; the other two shafts, the San Cosme and Nicolas, had encountered the ore pods at depths of 13 and 20 meters respectively (Newberry, 1883). At the same time a few opencuts and at least two more shafts existed as well, and one of the shafts, the Valencia, penetrated a large outcropping ore mass to a depth of about 7 meters. Newberry (1883) enthused that "the quantity of ore on the San Carlos property is without parallel among all the argentiferous [galena] deposits in the country."

The report of Stetefeldt (1889), while considerably less celebratory, argued nevertheless for a program of large-scale, mostly opencut mining and offered detailed suggestions for the building of infrastructure, securing of labor and transporting of ore. Stetefeldt (1889) noted that three loads of ore—about 20,000 pounds altogether—had recently been shipped by the (unnamed) Mexican mine managers, to be treated by lixiviation at the Ontario mill at Park City, Utah. The argentiferous galena in these three lots had assayed 5.5, 2.1 and 2.1 ounces of silver per ton, and some "selected specimens" had assayed as high as 11 ounces of silver per ton and 25% lead.

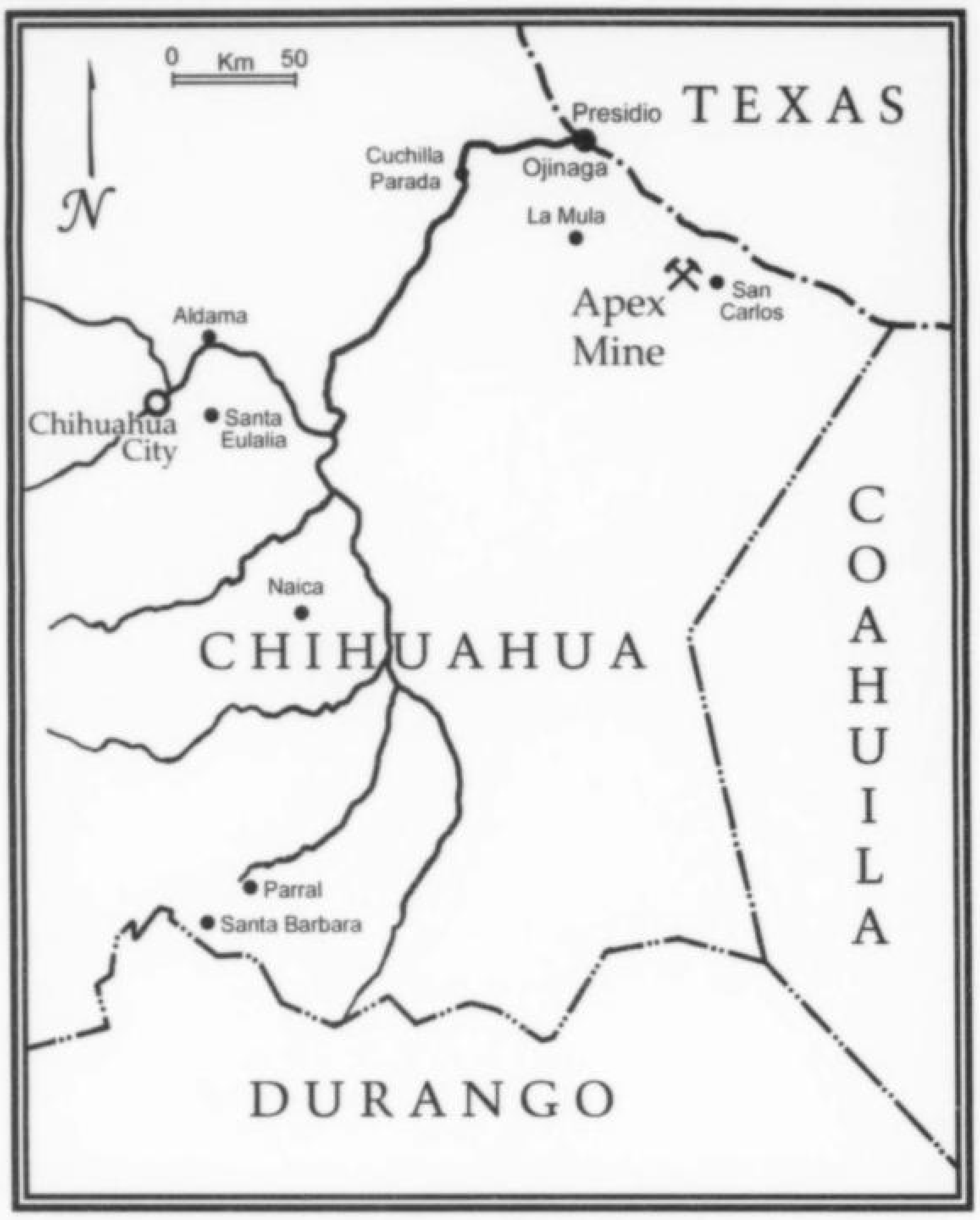


Figure 1. **Location map.**

Despite these promising early signs, no large-scale mining of the San Carlos deposit appears to have taken place before the early 1930s, when the United Verde Extension Company undertook commercial development. A few years later the Apex mine was being worked by a subsidiary of the American Smelting and Refining Company (ASARCO), whose activities at the mine lasted until 1952. During this short period the deposit was exploited by opencut excavations in an area about 500 meters long (along a northwest axis) by 300 meters maximum width, to a depth of 3 to 15 meters, producing about 1 million tons of lead ore (Hewitt, 1970). Since 1952 the site has stood abandoned, visited only (and that very infrequently) by mineral collectors searching for vanadinite and wulfenite crystal specimens.

In 2003, about 400 acres of the abandoned mine property were acquired in a government lottery by Top Gem Minerals of Tucson, a wholesale specimen dealership (Mike New, personal communication, 2007); however, the site still lies idle as of 2008.

COLLECTING HISTORY

The fame of the Apex mine among mineral collectors rests on two species, vanadinite and wulfenite, which have been found as beautifully crystallized specimens. The natural assumption is that these lead species (as well as the mediocre San Carlos mimetite specimens which have occasionally appeared) came from secondary mineralized zones in or around the argentiferous galena pods (see below). But despite considerable searching, no written accounts of crystal pockets as encountered in the mine, or any preserved stories of *in situ* collecting, have been found; these may be lacking because most collecting was done by local residents unconcerned with preserving "history."

San Carlos mineral specimens were first seen on the collector market in the early 1950s: presumably these were specimens dug by the miners and stockpiled until around the time when mining ceased. The most commonly marketed San Carlos species by far has always been vanadinite: a typical notice, placed in *Rocks & Minerals* by the dealer Hugh Ford in 1952, offers "Vanadinite, San Carlos, Mexico. Scarlet & brown xld. mass. 2.5 × 2—$2.50." Specimens showing red-orange vanadinite crystals associated with calcite are distinctive enough that when individual pieces were offered for sale, even in the absence of precise locality attribution, collectors would surely have recognized them—e.g. "Vanadinite, Chihuahua, Mexico: excellent miniature of subparallel groups of orange to reddish curved crystals to 1.5 cm, with partial coating of small calcite crystals, no matrix; 5.2 × 4.2 × 2.7—$25.00" (Dr. David Garske, Elmhurst, IL, specimen price list, 1978).

Former mineral dealer Jack R. Young, now of El Paso, Texas, recalls that at some time during the 1970s, he and an assistant collected fairly intensively in the old mine workings and took out a small number of fine vanadinite/calcite specimens, with vanadinite crystals to 2 cm. But Young decided that there was insufficient potential for the recovery of fine specimens to justify longer-term work there, so he called a halt to the project (Jack R. Young, personal communication, 2008).

Field trips to the site by casual collectors have largely gone unrecorded—but in the February 1967 issue of *Lapidary Journal*, Harry F. Miller and Ronald L. Olson wrote of their visit in autumn 1966 to nearby Santa Eulalia, during which they acquired some fine San Carlos vanadinites from a "local." Their account is probably typical of the mode by which specimens of San Carlos material began their journeys to collectors' cabinets during the 1950s, 1960s and 1970s:

> This year, strange to say, we found very little Santa Eulalia material that we wanted . . . However, we did find something even better. We were told that there was a young man at the company office who had an outstanding specimen for which he was asking a stiff *precio fijo* (fixed price). The man proudly brought out a vanadinite, and what a vanadinite! The matrix, about four inches wide, was covered with big red hollow crystals . . . The cluster came from the San Carlos mine over near the Rio Grande, a famous location. The proud possessor told us that various gringos had bid on it and that one of them had come within three dollars of meeting his price; however, he had made up his mind to get such and such a price and that was that. We didn't argue; we just paid up and were glad to do so, for the vanadinite was as nice a one as we had ever seen. We would be willing to wager that the lad who stopped three dollars short is still kicking himself. Only when the transaction was finished did he tell us that a couple of *gambustinos* had gone over to San Carlos and had brought back not only the specimen we had just acquired but several more. So we moved next door, where a young man was waiting for us. He brought out a big box and began to lay out vanadinite specimens on the floor. None of them came up to our first purchase in quality but they were very good indeed. They varied in size from one to four inches; some had scattered crystals that were a transparent ruby red. Others were a brownish yellow and others were brown. In general, only the brownish yellow ones had hollow crystals. What wonderful trading material! So we picked out several nice specimens and started bargaining for them. The young man knew that we had paid a fat price for the prize specimen and that marked us as *gringos ricos*; his original asking price on the lot was about four times what they were actually worth. After a spirited bargaining session enjoyed by the participants plus a half-dozen spectators, we shook hands on a satisfactory figure. Then the young man told us he had a personal collection for sale. There were more than fifty pieces but only six of them were outstanding. The rest were on the

Figure 2. **Mine openings in the hillside, Apex mine, San Carlos. Peter Megaw photo.**

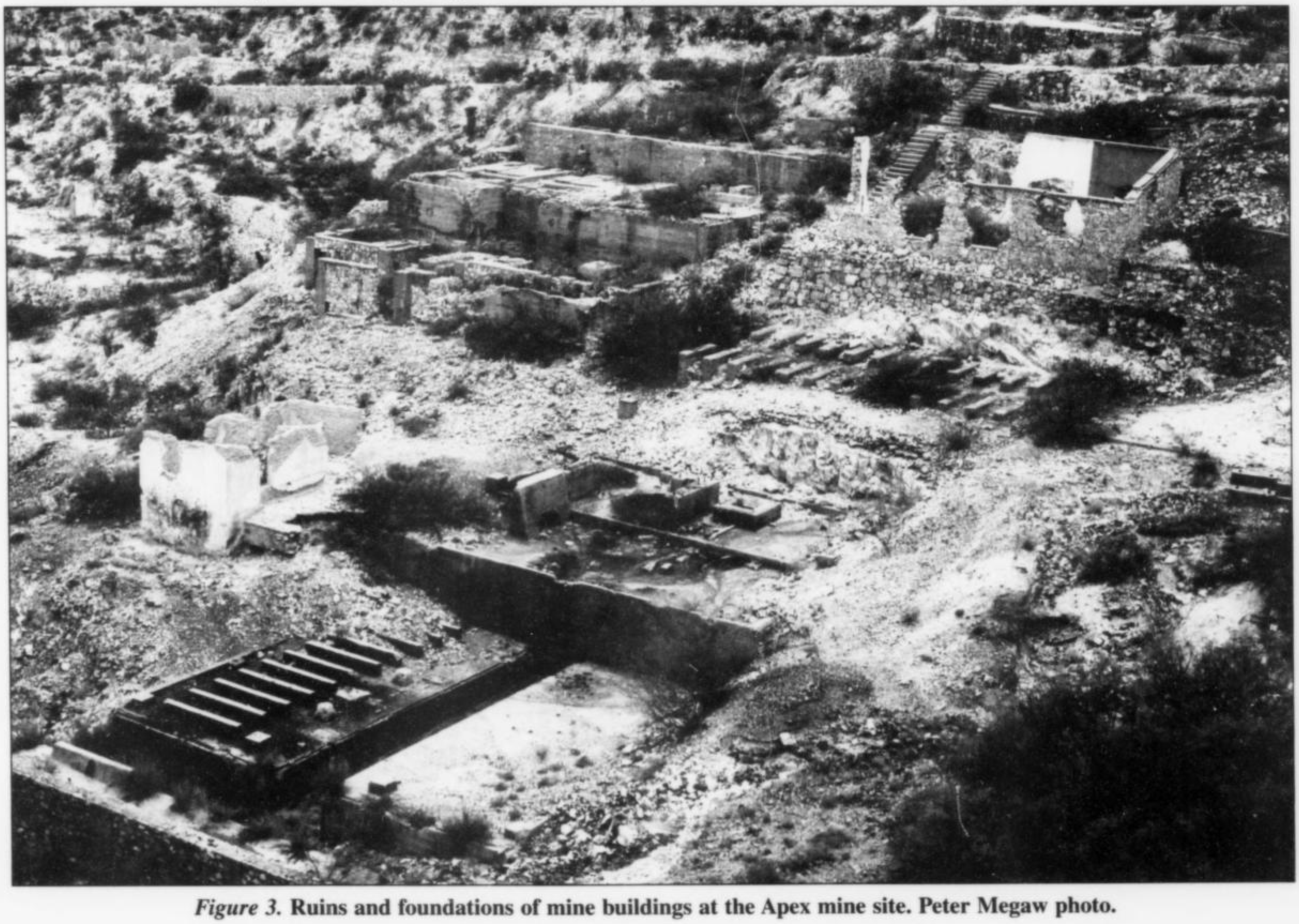


Figure 3. **Ruins and foundations of mine buildings at the Apex mine site. Peter Megaw photo.**

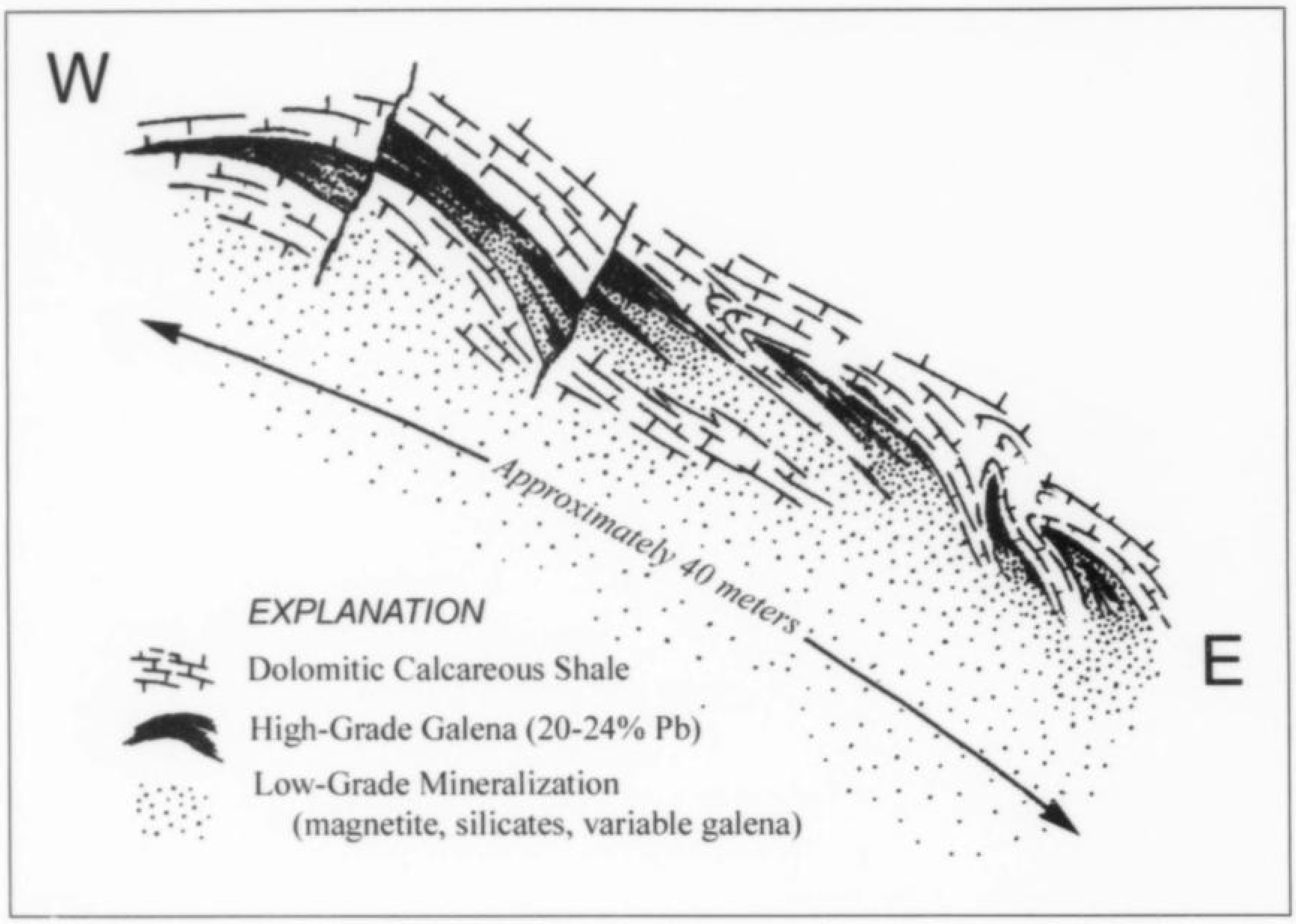


***Figure 4.* Vertical section through the top of Apex mine ore zone facing north along the northeast flank of the deposit (from Hewitt, 1970).**

junky side, even including such things as tumbled stones. But it was all or nothing, so we passed it up.

Wulfenite specimens from the Apex mine are much rarer than vanadinite specimens. Wulfenite from San Carlos first appeared on the market in the early 1970s (White, 1972), at which time Richard Bideaux noted that the wulfenite had first emerged "several years ago" and that "This district used to provide rich vanadinite specimens, but without evidence of associated wulfenite" (Bideaux, 1972).

During the 1970s, a number of fine Apex mine wulfenite specimens were handled by two Tucson dealer-collectors, Dan Caudle and Clayton Gibson (Mike New, personal communication, 2007). Later market appearances of Apex mine wulfenite may represent later discoveries, but were most likely just a recycling of older pieces. Scovil (1997) records an offering at the 1997 Spring Denver Show of a few San Carlos specimens with sharp, gemmy, bright orange wulfenite crystals to about 1 cm, but the year in which these were collected is not recorded.

GEOLOGY AND MINERALIZATION

The San Carlos orebody is a stratiform replacement deposit of magnetite, later fragmented by widespread faulting and then infused, probably in distinct hydrothermal pulses, by sulfides, most notably the argentiferous galena which was of ore interest during the Apex mine's brief lifetime. This is one of the many lead-zinc replacement deposits which occur in the 2,200-km belt of folded Mesozoic-age carbonate rocks in northeastern Mexico called the Mexican Fold Belt (Megaw, 1996). "Replacement" deposits are so called because they are characterized by *in situ* replacements of limestone or dolomitic rocks by sulfides and/or silicates introduced by the action of hydrothermal fluids which emanate, in most cases, from intrusive igneous stocks. When the replacement bodies are roughly horizontal they are called "blankets" or, in the Spanish term of accustomed use, *mantos*. (When the replacing bodies are steeply inclined or near-vertical they are called "chimneys"—but the San Carlos replacement bodies are of the *manto* type).

In the San Carlos area, calcareous sedimentary rocks of Upper Cretaceous to Lower Cretaceous age (Hewitt, 1970) are conformably underlain by siliceous sedimentary rocks ranging from very fine-grained quartzites to conglomerates with pea-size grains. Intrusions of felsic igneous rocks, variously described as syenite, granite, diorite and monzonite, intermittently penetrate the sedimentary sequences; some contacts of these intrusions with the quartzites are exposed in the southeast-striking *barranca*.

Shaly limestones and marls, chiefly of the Glen Rose Limestone formation, are exposed at the surface around the Apex mine, but this is the weathered crest of an anticline and the calcareous rocks are only 12 to 20 meters thick above the contact with underlying quartzites. Along this contact lie the mantos of magnetite mineralization. At an undetermined time after the mantos were formed, block faulting accompanying the formation of the anticline cut the quartzite-limestone contact, and with it the mantos, into many segments. At some still later time, pyrite and sphalerite were hydrothermally deposited in countless fractures in the faulted rocks. Hewitt (1970) argues that *still* later fracturing and hydrothermal activity are responsible for emplacement of the fine-grained sulfide pods, up to 25 meters thick, which are found near the top of the deposit, i.e. at the site of the Apex mine, at the anticlinal crest.

The major replacement bodies consist largely of massive magnetite, pyrite and hematite and other iron oxides, with concentrations of sulfides, chiefly galena and sphalerite, present locally. In the topmost and richest part of the deposit, galena and magnetite concentrations occur in overlapping lenses which are broad and low-grade in their basal (eastern) segments and narrow and high-grade in their (western) segments.

Dense, bluish green to black masses of metamorphic silicate minerals (chiefly staurolite, actinolite and garnets) underlie the richest magnetite concentrations. Hewitt (1970) argues that the magnetite/silicate mineralization along the quartzite-limestone boundary resulted from a combination of contact metamorphism and simultaneous hydrothermal activity, and that in the most highly altered zones the original magnesium-rich limestone was wholly replaced by magnetite, staurolite, actinolite, garnet and recrystallized dolomite.

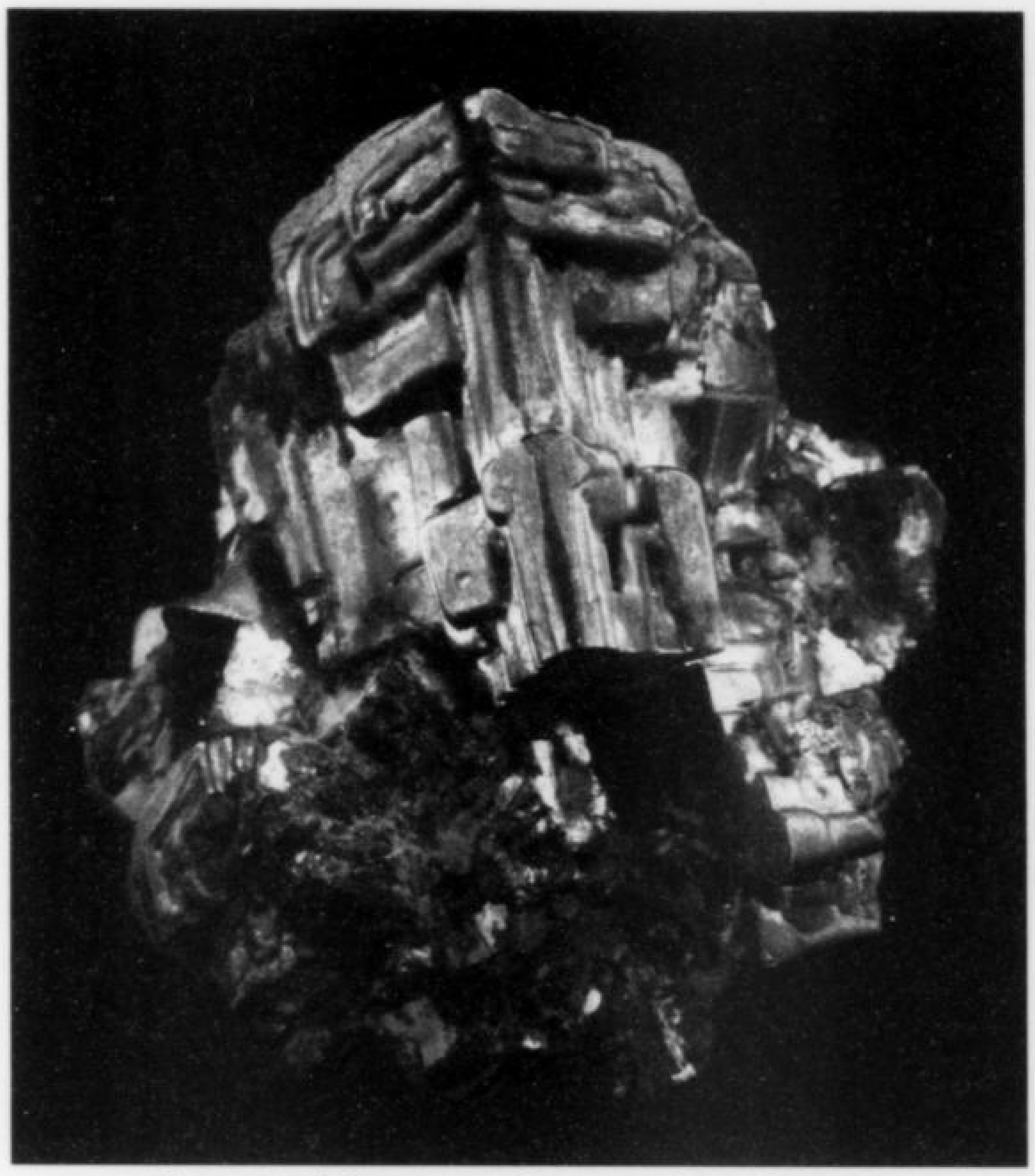


Figure 5. Galena crystal group, 4 cm, from the Apex mine, San Carlos. Peter Megaw collection; Jeff Scovil photo.

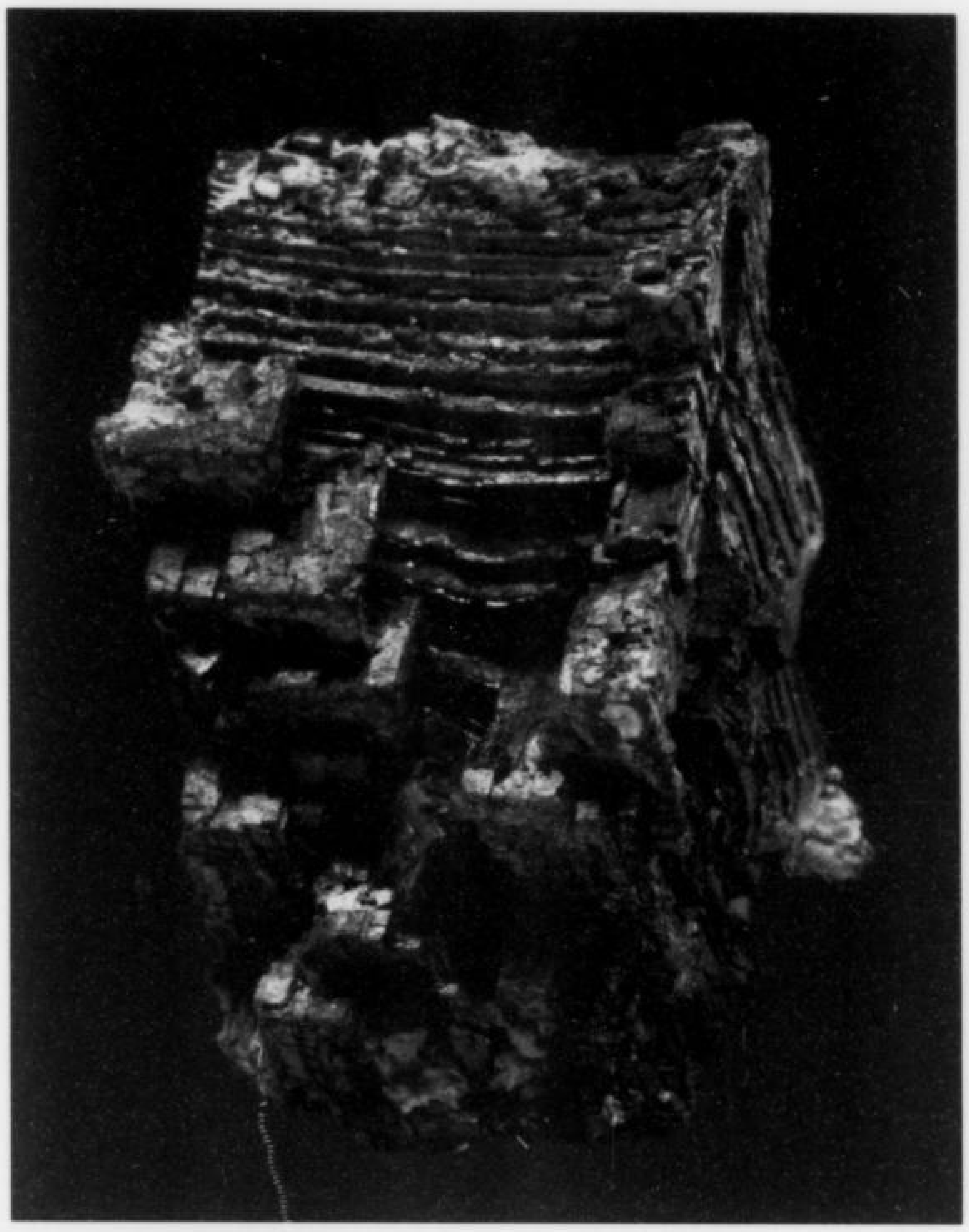


Figure 6. Galena crystal, 4 cm, from the Apex mine, San Carlos. Peter Megaw collection; Jeff Scovil photo.

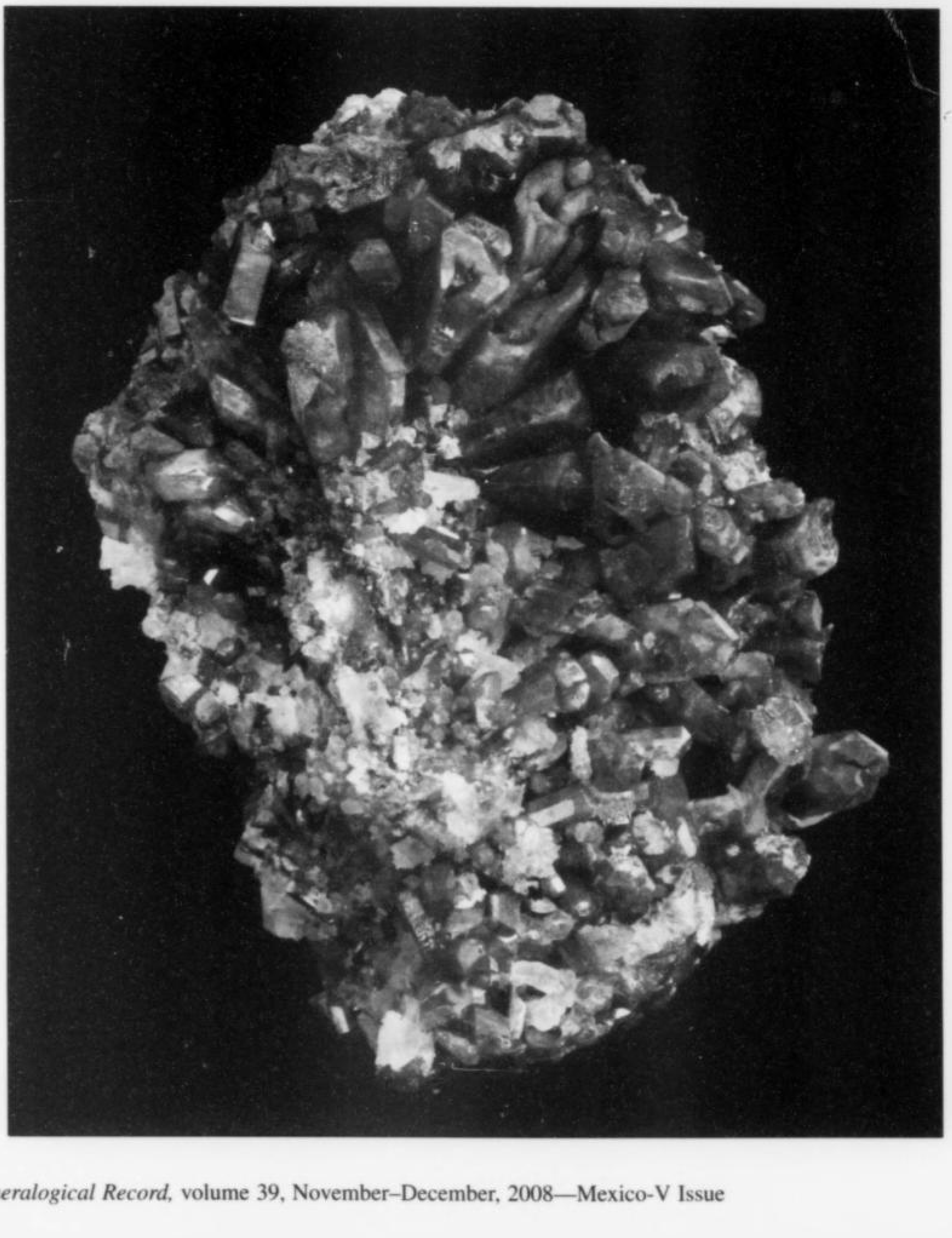


Figure 7. Vanadinite crystals intergrown with calcite crystals, 10 cm, from the Apex mine, San Carlos. Miguel Romero collection; Arkenstone specimen, now in the collection of Ed David. Jeff Scovil photo.

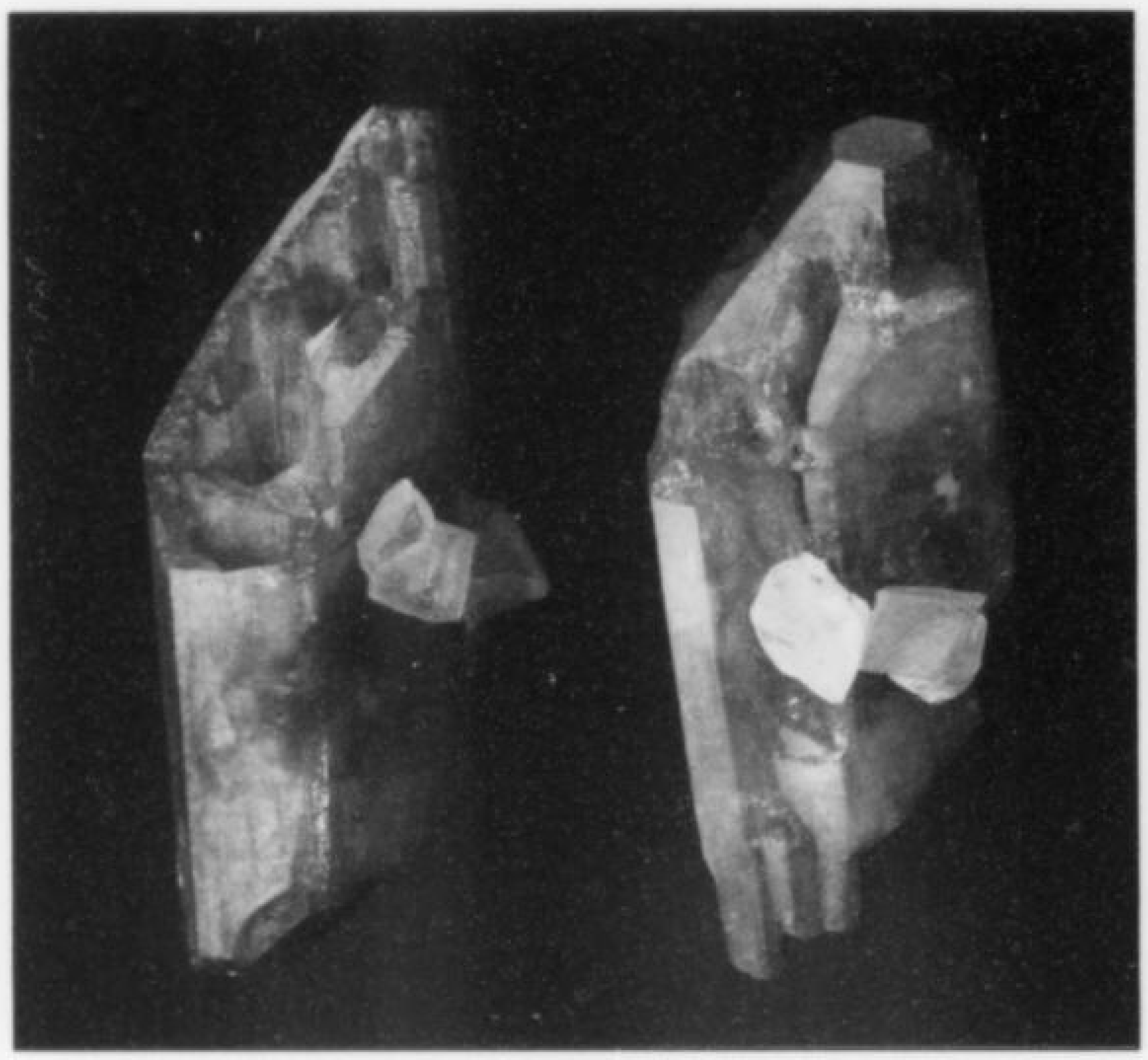


Figure 8. A 3-cm vanadinite crystal (two views), from the Apex mine, San Carlos. Key's Minerals specimen and photo.

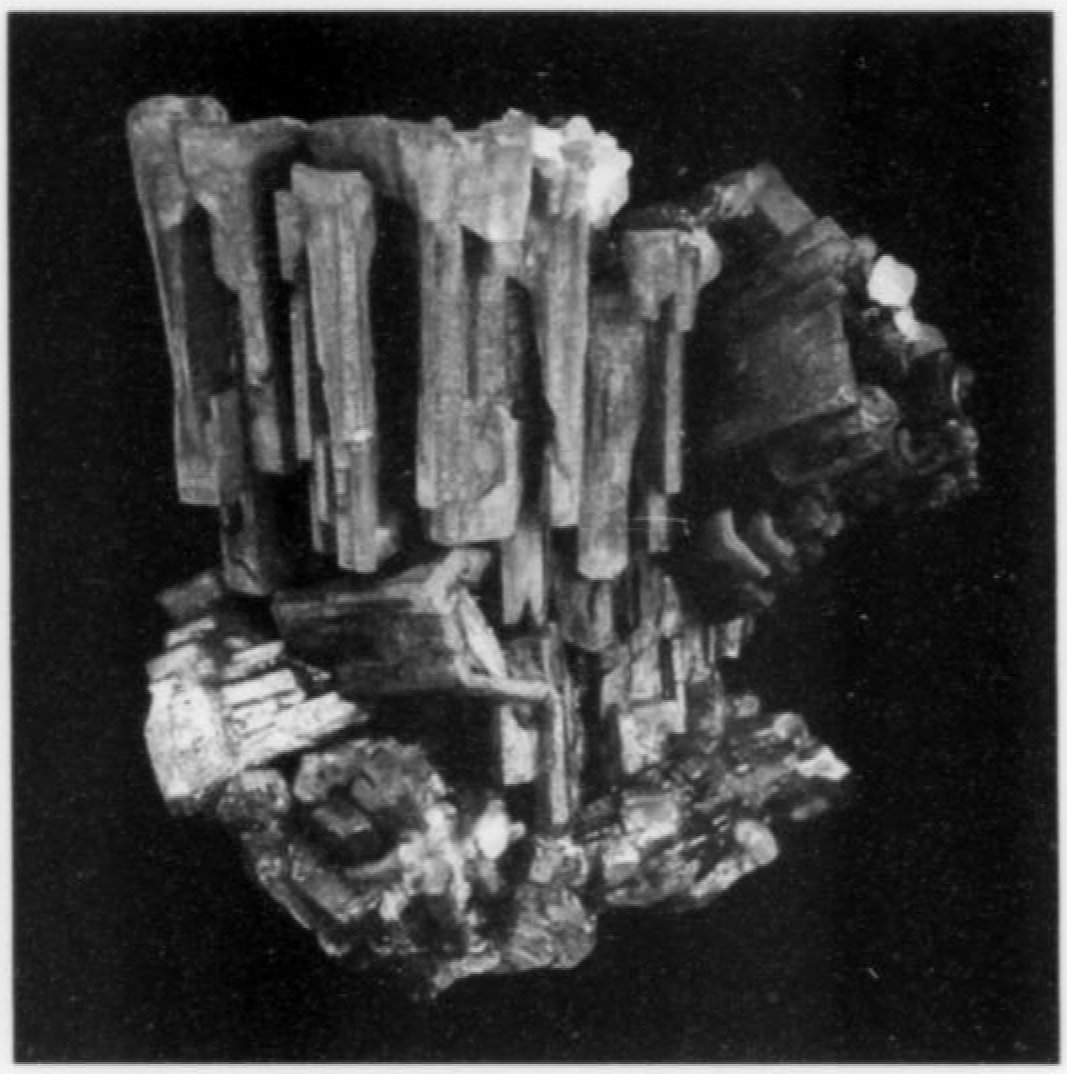


Figure 9. Vanadinite crystals in parallel growth, about 2 cm, from the Apex mine, San Carlos.

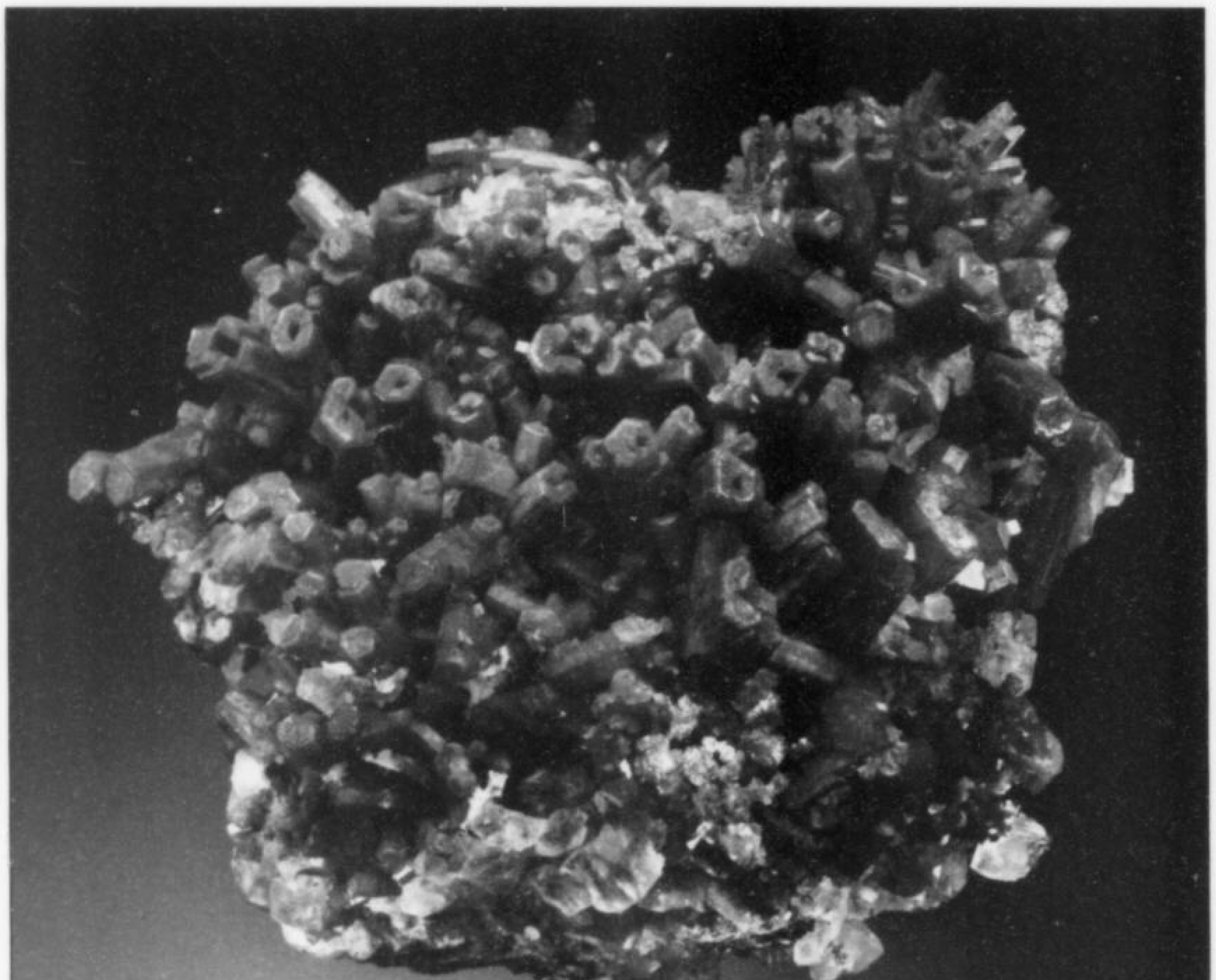


Figure 10. Vanadinite crystal group with calcite, 8.5 cm, from the Apex mine, San Carlos. Miguel Romero collection, now in the Peter Megaw collection; Jeff Scovil photo.

MINERALS

No available source lists the species found in the magnetite bodies, much less in the country rocks, of the mine area. The following species descriptions are based on material which has reached the specimen market, probably from the sulfide pods which were mined as ore. Aside from galena, the sulfides occurring in those pods—bornite, chalcopyrite, pyrite, sphalerite—seem to have been found exclusively in massive form. Details regarding the collector-quality species are as follows:

Calcite $CaCO_3$

The most distinctive-looking and most widely distributed mineral specimens from the Apex mine show orange-red to yellow-brown vanadinite crystals intergrown with lustrous, translucent white

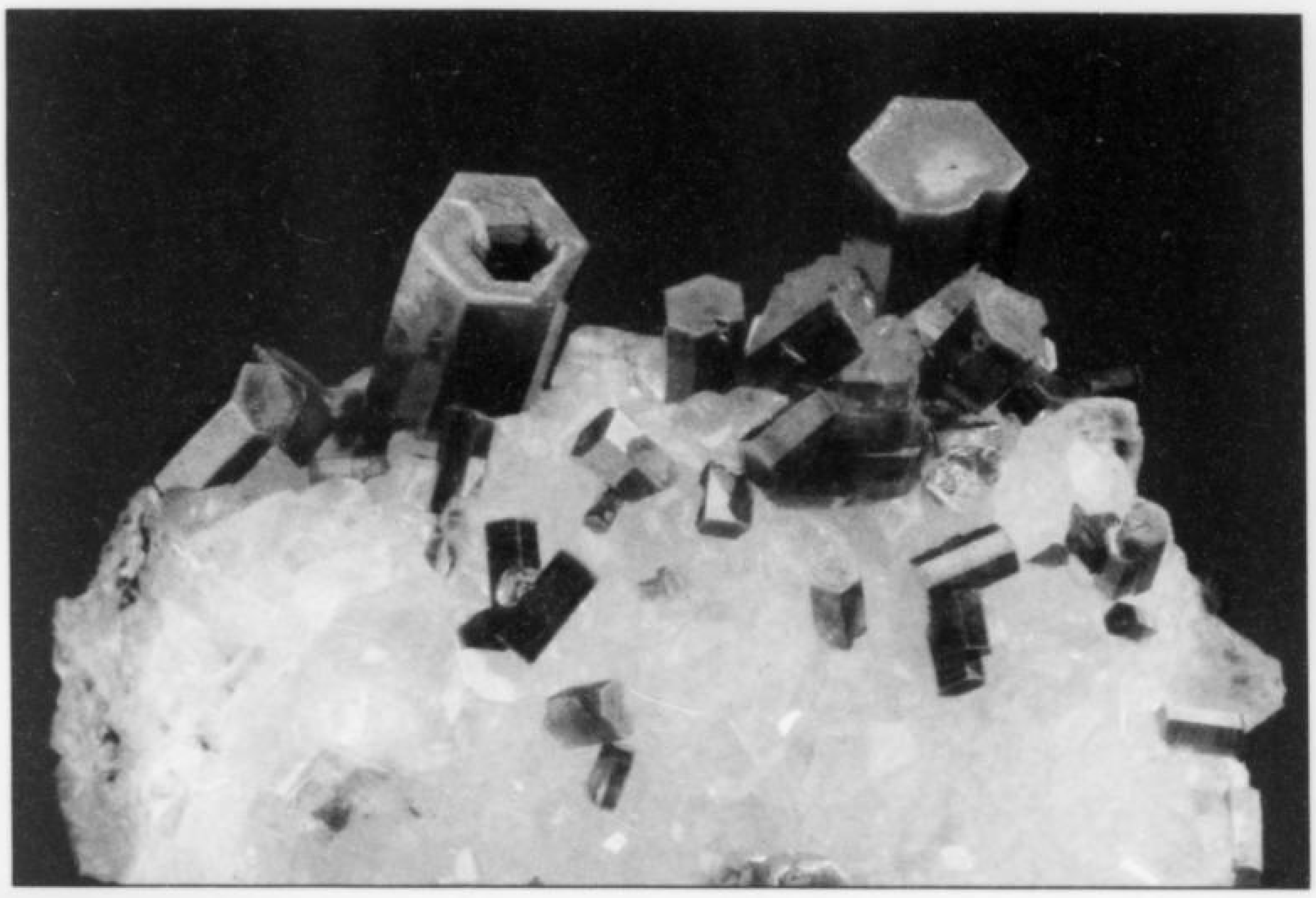


Figure 11. **Vanadinite crystals (one showing a cavernous opening) on calcite, 3 cm across, from the Apex mine, San Carlos. Peter Megaw collection.**

Figure 12. **Calcite crystals perched on vanadinite crystals, 2.5 cm, from the Apex mine, San Carlos. F. John Barlow collection; Malcolm Hjerstedt photo.**

crystals of calcite, the latter rarely exceeding 1 cm. The vanadinite crystals mix intimately with the calcite crystals and in some cases penetrate or impale them, resulting in attractive red-and-white specimens which may reach cabinet size. The few rare wulfenite crystals known occur typically on druses of small white calcite rhombs.

Galena PbS

Argentiferous galena was the chief ore species found in the sulfide pods. Rarely, it occurred as dull gray, somewhat crude, hoppered cubic crystals in parallel aggregates to several centimeters (Peter Megaw, personal communication, 2008).

Hedyphane $Pb_3Ca_2(AsO_4)_3Cl$

Hedyphane, a rare member of the apatite group, was occasionally found at San Carlos as yellow microcrystals in clusters to a few millimeters (Panczner, 1987).

Hematite (?) Fe_2O_3

Rob Lavinsky's *The Arkenstone* dealership once handled a lustrous, jet-black, thumbnail-size cluster of distorted rhombohedral hematite crystals purportedly from San Carlos. Massive hematite is a minor constituent of the magnetite bodies which occurred in promixity to the San Carlos sulfide pods (Hewitt, 1970). The occurrence of good crystals, however, requires confirmation.

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

Hydrozincite, probably as small encrustations, has been noted from San Carlos (Panczner, 1987).

Mimetite $Pb_5(AsO_4)_3Cl$

According to Panczner (1987), mimetite occurs at San Carlos as botryoidal masses associated with vanadinite and calcite; Cook

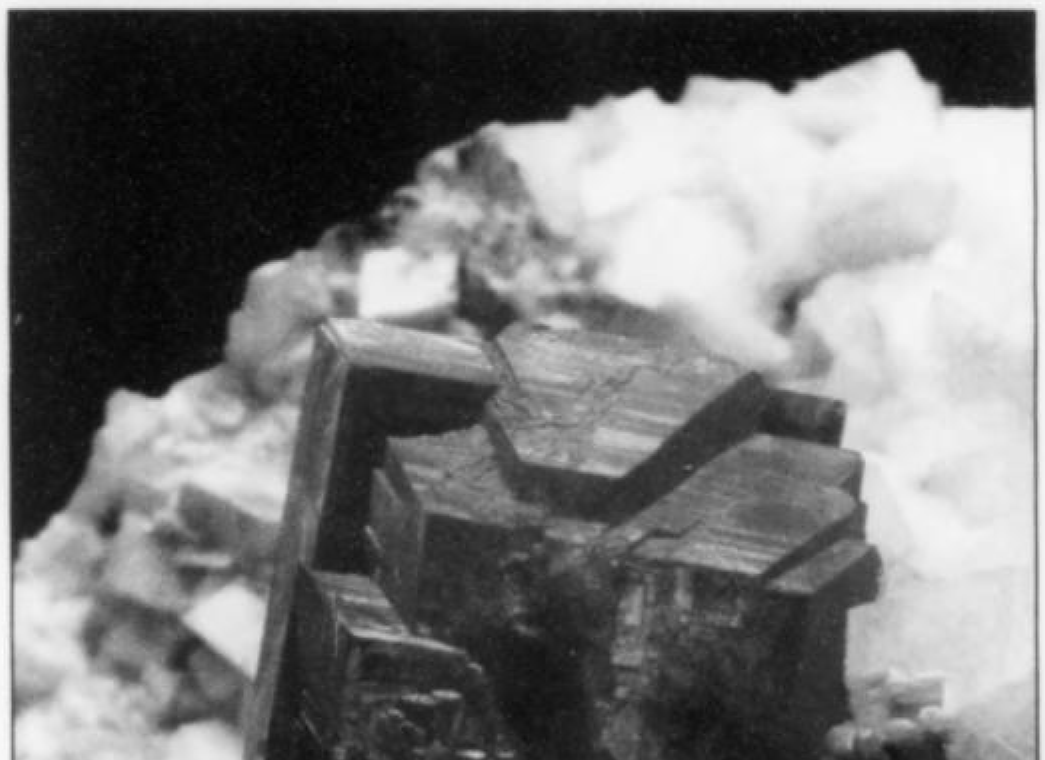


Figure 13. **Wulfenite crystal, 2.5 cm, on white calcite, from the Apex mine, San Carlos. Former Smithsonian specimen (1978), later in the Martin Zinn collection (2003). Jeff Scovil photo.**

Figure 14. **Wulfenite crystal cluster on white calcite, about 8 cm across, from the Apex mine, San Carlos. Formerly in the Phil Gregory collection (1976); Wendell Wilson photo.**

(2001) writes that "fine botryoidal masses of lemon-yellow mimetite from San Carlos . . . were once relatively plentiful." Mimetite has also been found as yellow, translucent, lustrous microcrystals, with individuals reaching about 7 mm, in masses to 7 cm across.

Vanadinite $Pb_5(VO_4)_3Cl$

Vanadinite is the best known well-crystallized species from the Apex mine. It occurs there as simple hexagonal prisms, in some cases modified by pyramid faces and commonly hoppered, to 6 cm (Panczner, 1987). The crystals are commonly intergrown with small, translucent white calcite crystals. The vanadinite crystals range from orange-red with medium luster to red-brown or brown. A dark brown skeletal habit may represent a high-arsenic variety similar to the well-known so-called "endlichite" specimens from Los Lamentos, Chihuahua. The crystals can occur scattered individually over matrix, and also as dense clusters, in some cases showing parallel growth.

Wulfenite $PbMoO_4$

Lustrous, orange to red-orange, simple tabular wulfenite crystals modified along the edges by a dipyramid perch on, or are partly embedded in, white to pale gray calcite, without vanadinite or other associated species (Bideaux, 1990). The wulfenite crystals reach 3 cm on edge (Mike New, personal communication, 2007), and are reminiscent of the famous specimens from the Red Cloud mine, but for the general lack of a second-order dipyramid which often renders the Red Cloud tablets octagonal rather than square.

As already noted, San Carlos wulfenite specimens are very much rarer than San Carlos vanadinite specimens. They reached the mineral market 20 years later, and did not remain available for long. The wulfenite occurrence in the mine was extremely localized and very limited in extent, and has probably been mucked in.

ACKNOWLEDGMENTS

I am grateful to Peter Megaw for directing me to (the few) extant print references on San Carlos, for permitting me to examine several San Carlos specimens in his superb collection of Mexican minerals, and for helpful discussions. For further helpful discussions I am indebted to Gene Schlepp, Mike New and Jack R. Young. Various photographs of San Carlos wulfenite specimens were located by Wendell Wilson, and Peter Megaw kindly provided snapshots of the Apex mine site and adjacent desert vistas.

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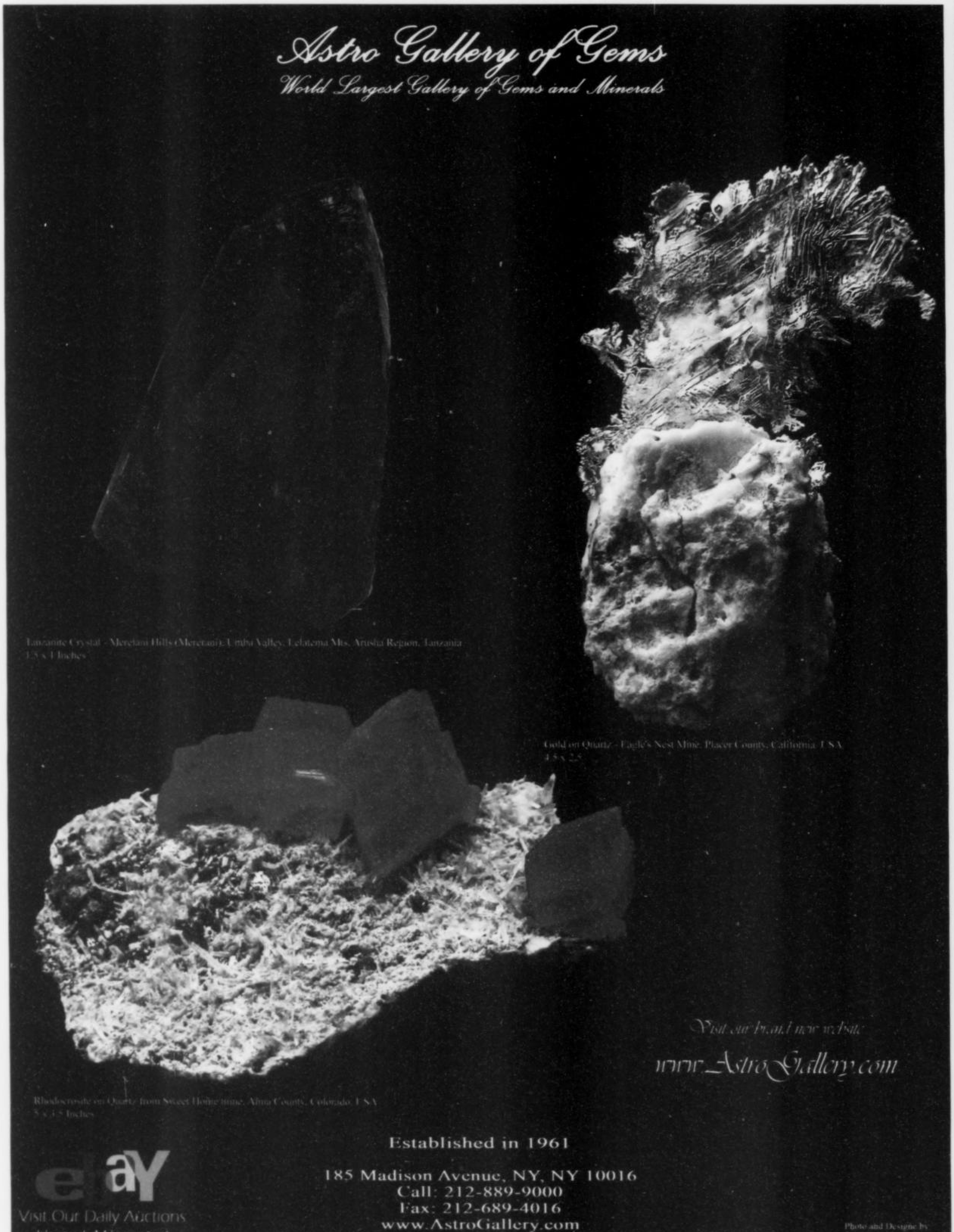
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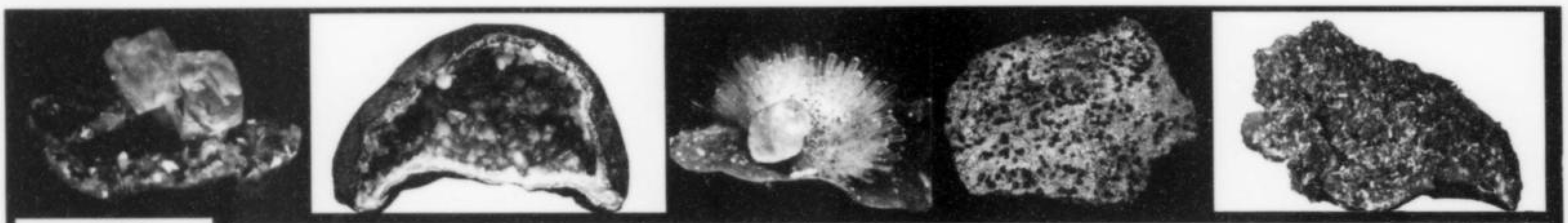


Classic Agate Deposits

of Northern Mexico

Brad L. Cross
810 East Olympic
Pflugerville, Texas 78660

Mexican agates were first mentioned by Kunz in 1902. However, it wasn't until 1945, when Mexico Federal Highway 45 was constructed, that commercial quantities began appearing on the market. Various regions of northern Chihuahua continue to produce some of the most vividly colored and attractively patterned agates known to man. The growing popularity and displayability of these agates as specimens qualify their localities as among the classic mineral occurrences of Mexico.

INTRODUCTION

Since the mid-1940s, Chihuahua has produced some of the world's finest agate specimens. Although in the past they have not always been readily accepted into mineral collections, today the finer and rarer pieces are vigorously pursued by collectors. Laguna, Coyamito, Agua Nueva, Apache, and Moctezuma are just a few of the classic localities that produce some of the world's most dazzling agates. The names are derived from the ranches on which the agates are found, or the nearest railroad station, or perhaps a nearby village.

The early prospectors and collectors who discovered each of the agate beds were drawn from the ranks of accountants, physicians, legislators, attorneys, machinists, gamblers, and even the penniless; many were highly unusual characters. Several of the pioneers were so convinced of their own superiority that they were destined to collide with each other. In their attempts to outdo each other as collectors or owners of the finest agate specimens, they promoted discovery and exploitation of some of the richest agate beds in the world. Without their jealousy and hatred of one another to motivate them, they would not have accomplished as much as they did.

Mexican agates show most of the features known in agates of volcanic origin worldwide. Moss, plume, sagenite and banded (fortification) agates are found throughout the country. This article concentrates on several of the more popular types of rare banded varieties of agate from Northern Mexico, and provides precise geographic coordinates for several of the more important localities.

Museum-quality agates have never been plentiful, even in the 1940s, when large-scale surface collecting began. High-quality banded agates with bright, contrasting colors, complete patterns, no fractures or cracks, and no crystalline quartz centers have always constituted only a very small percentage of the whole (on the order of 3% or less). The highest-quality specimens command prices comparable to those of the finest crystal specimens from Mexico.

Agate bands form in scalloped and undulating layers that more or less follow the shape of the original vesicle or vein. It is not at all unusual for the bands to make sharp, angular turns that resemble the parapets of old fortresses: thus the term "fortification" agate. The bright, vivid colors found in Mexican agates surpass the range of colors common for most individual mineral species, and the pseudomorphs of agate after aragonite are among the best found anywhere.

There are currently over 100 different varieties of agate from Mexico; a number of observable features which are characteristic of the various types of banded agates are key in distinguishing one variety from another. These characteristics include color dominance, nodule size, exterior rind, distinctiveness of banding, inclusions, presence of pseudomorphs, and weathering.

Much of the Mexican agate story begins with the Rancho El Agate andesite flows some 38 million years ago (Keller, 1977). These ancient flows contained gas vesicles that later became filled with silica and various coloring agents (primarily iron and manganese oxides) to

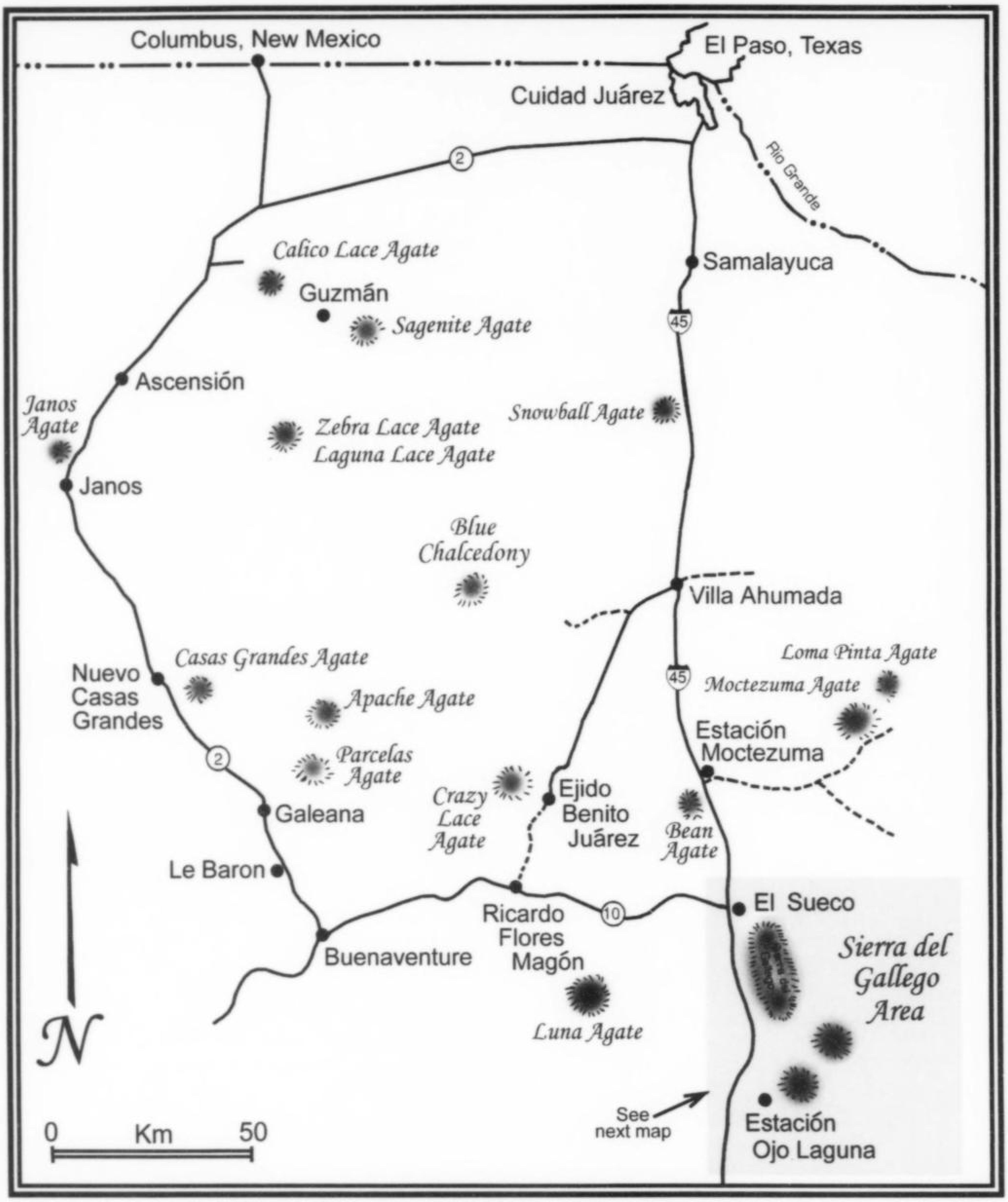


***Figure 1.* Famous agate occurrences in the state of Chihuahua.**

produce some of the most exquisite specimens in the world. Weathering and erosion broke down a portion of the flows, and the more resistant agates were freed from their host and scattered across the desert floor. Most of the early agates were found as residual surface nodules, although some limited hand digging was done. In the early 1960s, pits and trenches were dug into the tenacious andesite, with no guarantee of success to their diggers. It wasn't until the early 1990s that mechanized mining with heavy machinery began, but even today such mining is sporadic. Although some of the older deposits are probably now depleted and offer little to no mining potential, others still hold the promise of yielding good agates.

The agate-producing region in Mexico begins north of Villa Ahumada, Chihuahua and extends in a southerly direction for the next 80 miles to Estación Ojo Laguna. The belt then trends to the west-northwest to Casas Grandes (where the Casas Grandes, Parcelas, and Apache varieties occur) and on up into southern New Mexico. The loop is then complete if you travel back to the east-southeast and include the popular Mexican Crazy Lace beds found southwest of Villa Ahumada.

SELECTED AGATE VARIETIES

Agua Nueva Agate

Hacienda Agua Nueva on Rancho Los Nogales, Chihuahua, lies about 135 miles south of El Paso, Texas, in the southeast quadrant of the Sierra del Gallego (host to the Sueco, Gallego, Derramadero, Agua Nueva, Aparejos, and Coyamito varieties). The northernmost portion of the sierra begins about 120 miles south of El Paso. The agates from this region all originate in what is locally known as the Rancho El Agate andesite, a 38-million-year-old porphyritic andesite. Over the years, this ranch has produced a wide range of agate varieties, including both nodular and vein types. Various isolated areas of the ranch produce specific types of agate with characteristics particular to that area.

Many of the nodules from this ranch contain bands brightly shaded in lavender, purple, gold, pink and yellow. The nodules typically have a gold moss on the outside rim and weigh from a half pound up to 60 pounds. Less than a mile away, the agate occurs as a vein, containing brilliant purple and white bands. Characteristic of this vein are the stunning purple, lavender, and white tubes, some reaching over an inch in diameter. When cut perpendicular to the tube, the concentric bands produce a beautiful "eye," making a splendid addition to any collection.

The first serious mining operations on Rancho Los Nogales were conducted by Francisco Olivas (from Ciudad Juárez, Chihuahua) in the mid-1970s. In recent years, the various deposits on this ranch have been commercially mined by Eugene Mueller of *The Gem Shop* in Cedarburg, Wisconsin, under the mining concessions *Mi Sueño* ("My Dream") and *Agua Nueva* ("New Water").

Apache Agate

Apache agate is perhaps one of the most mysterious agates ever found, not only in Mexico but worldwide. Its bright red, vivid orange, and dark yellow colors seem to be suspended in contrasting blue and lavender agate with color patterns resembling splashes, draped folds, and swirling veils. The agate always has a very finely pitted, rough, lime-green exterior that makes it easily distinguishable from other Mexican agates.

The finest museum specimens are obtained from nodules which have cavities showing on their surfaces. It is adjacent to these cavities that the most exquisite patterns and colors tend to occur.

Apache agate is found approximately 5 miles northwest of Ejido El Apache on Rancho La Viñata (about 30 miles southeast of Nuevo Casas Grandes, Chihuahua). The agate deposit was initially discovered in 1957 by Luis Arzola and Jesús Gamon (both from Ciudad Juárez, Chihuahua), and was intermittently worked by hand for a number of years. In 1968, our dear friend Benny Fenn filed claim on the deposit and, with his brother-in-law Harold Jorgenson, extensively worked the area with heavy machinery, producing hundreds of pounds of exquisite agate. Little has been found since then.

This locality produced what may be the world's most famous single agate, known as "the Apache Hooded Owl" (Fig. 44). The agate weighs approximately 1.5 pounds and is an excellent example of a scenic agate.

Aparejos Agate

Aparejos agate is found on Rancho Los Aparejos, located approximately 3 miles north of Rancho El Agate and on the northeast side of the Sierra del Gallego. The agate was mined in the 1950s from three pits (average 10 feet square and 4 to 6 feet deep) hand-dug into very dense Rancho El Agate andesite.

The distinct banding and the exterior rind make this agate variety almost indistinguishable from the Coyamito agate. Reportedly, much of the fine purple and yellow banded agates once marketed as Coyamito agate actually came from the *La Morenita* ("The Dark Girl") claim on Rancho Los Aparejos. Other colors found in agates from this ranch include red, yellow, white and blue. Sr. Beto Vasquez (from Ciudad Juárez) was the first to commercially mine Aparejos agate. Beto began collecting nodules and digging pits at Aparejos in 1955, for Manuel Ontiveros (one of our past great mineral dealers).

Casas Grandes Agate

Approximately 10 miles southeast of Nuevo Casas Grandes in the Cerros Las Borrogas area is Rancho Colorado and the *La Chocolata* claim, regarded as the original locality for Casas Grandes Agate. The banding in this agate is predominantly lavender, gray, white, slate and pink.

The agate was named for its proximity to Nuevo Casas Grandes, a town founded in 1879 as a railroad station on the *Ferrocarril Noroeste de Mexico*. Up to two-thirds of the nodules from this location are considered "duds." What may appear to be a perfectly solid agate on the outside turns out to be solid psilomelane or other manganese oxides on the inside. The Casas Grandes agate has an extremely smooth skin that is dark brown to reddish brown and occasionally gray. About 50% of the agate nodules contain crystalline quartz centers.

The agate nodules were initially discovered around 1955 and were mined from an altered grayish purple andesite. The most recent mining operation was conducted in the early 1970s by Benny Fenn; it involved the terracing of the mountainside with a small bulldozer. Once a pass was made with the bulldozer, the exposed ground was then searched for agate nodules. Jesús Gamon and Ramon Peña are the men who worked most of this deposit in the late 1950s and early 1960s.

Coyamito Agate

Coyamito agate, commonly containing brilliant shades of red, orange, yellow and purple, is indeed among the very finest agates to come from the Sierra del Gallego area. Agate was first picked up at Rancho Coyamito Norte in the early 1940s by Dave and Lucille Harris of El Paso. In 1948, Ramon Peña filed the first commercial claim at the ranch and worked the deposit for Manuel Ontiveros. Numerous others have since staked their claims in the area; agate has been produced most recently by the ranch owner, Marin Carrillo.

Some very rare color combinations are found in this agate, including purple and yellow, rose and white, various shades of red, purple, and mustard. Many of the Coyamito nodules prove to be hollow, and in many cases a hollow Coyamito will have concentrically ringed cylindrical tubes running through it, producing an attractive "eye" when cut perpendicular to the tube.

There are three primary deposits of agate on the ranch. The *Los Alamos* ("The Poplars") area is the most southerly and is named for the large trees surrounding a spring which once served thirsty explorers and travelers. The agate here occurs adjacent to the creek bed, and is noted for its dark lavender and yellow bands that in many cases cover pseudomorphs of agate after pseudohexagonally twinned aragonite crystals. The agate occurs as nodules ranging from a few inches to more than 12 inches in diameter. The exterior of many of the nodules from this deposit consists of a rust-orange to red, powder-like "limonite."

Just up the hill and only a few hundred yards away is the *La Fortuna* deposit. Agates from this deposit typically have bright red, pink, orange, yellow, tan and white banding. This nodular agate is completely different in size, external features, and banding color from the *Los Alamos* agates. The nodules are usually smaller, averaging under 4 inches in diameter; their dark red to brown, siliceous exteriors lack the rough "limonite" coating found on nodules from the *Los Alamos* deposit; and their external textures are much smoother, with small pin-size pits.

The third deposit at Coyamito Norte consists of an area known as *La Sonoreña*. This deposit is located in the far northern portion of the ranch adjacent to and extending into Rancho Derramadero. While the smooth-skinned nodules here are somewhat small for the deposit (averaging 1 to 4 inches in diameter), these are perhaps the most colorful agates ever found at Coyamito. Brilliant reds, purples, yellows, and oranges are characteristic of this deposit. With many of the *La Sonoreña* agates, one can begin tracing an individual red band around the agate and find that it changes to yellow or orange. Nothing compares to the lovely agates found at this location.

Pseudomorphs of agate after pseudohexagonally twinned aragonite can be found at any of the three deposits. Specimens in which the entire agate itself is a pseudomorph can reach lengths of over 8 inches. It is not unusual to find combinations of purple and yellow bands and a vast array of pseudomorphs within the banded nodule.

Crazy Lace Agate

Crazy Lace or Mexican Lace agate is found in several remote areas of northern Chihuahua; however, the most noted occurrence is northwest of Ejido Benito Juárez in the Sierra Santa Lucia (located approximately 30 miles southwest of Villa Ahumada).

This material has been utilized for years in the commercial cutting of cabochons. The pattern generally consists of many irregular curved and twisted bands. There are zig-zags and scallops, bouquets, sagenites (acicular sprays), sunbursts, and eyes. Many of the internal structures have the appearance of very small, elongated tubes; these are commonly grouped together in larger, radiating spherical aggregates which can reach diameters of up to 4 inches. While most of this vein agate is white to gray, some pieces are naturally stained beautiful shades of red, orange and gold.

Unlike all the other Mexican agates, which are found in igneous environments, this variety is found in a Cretaceous limestone and occurs only in vein form.

Crazy Lace agate comes in several varieties and is usually named after the claim owner or after typical patterns in the agate. The first mining concession on this deposit was filed in 1960 by Beto Vasquez. Additional concessions were immediately filed by Victor Salgado and Juan Noriega (all from Ciudad Juárez). There are currently at least six active concessions in the Sierra Santa Lucia area and up to perhaps 100 separate diggings.

Gallego Agate

Rancho Gallego has been very prolific in supplying exceptional agate nodules. The nearby railroad station, *Estación Gallego*, was the primary shipping point for manganese ore from the Terrenates manganese district in the early 1950s. It was in 1946 on Rancho Gallego that the first banded agates of Northern Mexico were commercially collected.

The primary agate occurrence on the ranch is approximately 5 miles southeast of Sueco and 6 miles east of Highway 45, in the altered Rancho El Agate andesite that forms the rounded eastern slopes of Cerro del Gallego. No pits or trenches have been dug at Rancho Gallego, and little information has been found regarding early mining activities.

Gallego agate characteristically exhibits pink, light red, and gray banding. The bands are not particularly sharp or distinct in most nodules. All agate from the ranch is nodular in form, and it is estimated that 70% of the nodules are hollow. They are generally round and measure only a few inches at most in diameter; their rinds are most commonly chocolate-brown or pale pink.

Gregoria Agate

Gregoria agate occurs in the most southerly portion of the Sierra del Gallego, mid-way between El Sueco and Estación Ojo Laguna in the Cerro El Ahiujadero ("the calving area") on Rancho La Gregoria. The agate was mined in the late 1950s from several pits hand-dug into the very dense Rancho El Agate andesite.

The agate occurs as banded nodules and exhibits almost every color of the rainbow. Because of its fine and distinct banding, vibrant colors, and smooth exterior rind, it has usually been marketed as Coyamito Agate.

***Table 1.* Localities for some important types of Mexican agate.**

Agate Type	*Latitude*	*Longitude*
Agua Nueva	N 29-41-53	W 106-13-11
Apache	N 30-19-02	W 107-27-40
Aparejos	N 29-52-22	W 106-15-13
Blue Agate	N 30-35-37	W 107-01-05
Carneros	N 29-33-22	W 106-10-01
Casas Grandes	N 30-18-30	W 107-47-51
Coyamito	N 29-46-12	W 106-13-19
Crazy Lace	N 30-09-40	W 106-59-10
Derramadero	N 29-49-02	W 106-14-36
Gallego	N 29-49-18	W 106-21-04
Gregoria	N 29-42-04	W 106-15-58
Laguna	N 29-28-49	W 106-15-58
Las Choyas	N 29-31-27	W 105-56-47
Loma Pinta	N 30-13-34	W 106-12-58
Moctezuma	N 30-15-15	W 106-14-25
Parcelas	N 30-03-48	W 107-28-32
Sabinal-Guzman	N 31-07-54	W 107-27-03
Santa Gertrudas	N 27-46-50	W 105-39-26
Snowballs	N 30-55-21	W 106-31-15
Sueco	N 29-54-25	W 106-21-38

Laguna Agate

Laguna agates seem to be the most highly prized of all the Mexican agates. This is probably more a function of name recognition than of anything else, as there are other Mexican varieties just as fine in quality. Laguna agates have striking fortifications and a vivid range of colors including red, pink, orange, yellow, purple, lavender, beige, white and gray. The best examples have a combination of colors that provide contrast or a combination of "clash" colors such as purple, red, or orange. Shadow effect, an optical effect created by the perception of depth between the parallel bands of an agate, is not uncommon at this locality and gives the agate a dynamic visual appeal.

One of the most distinguishing features of the Laguna agate is the presence of blue-green celadonite as a coating on the exterior of most of the nodules. The shape of the nodules is roughly spherical or potato-like, with an extremely pitted, pockmarked and highly irregular surface. Laguna nodules range from the size of an egg to the size of a large cantaloupe; the average nodule is between 2 and 5 inches in diameter.

Laguna agate is mined east of Estación Ojo Laguna, a small railroad station about 145 miles south of El Paso. There are currently 13 separate concessions at this locality including *Ojo de San Martin, El Puerto, Laguna, Santa Monica, La Alianza, El Hormiguero, La Morita Uno, Buena Fe, Diana, El Mezquite, El Mezquite 1, La Morenita,* and *Ojo Laguna.*

Las Choyas ("Coconut") Geodes

While numerous deposits of geodes and thunder eggs are found throughout the Republic, the largest and most abundant deposit of geodes in Mexico occurs at Las Choyas, about 22 miles east-northeast of Laguna Enciñillas and 145 miles south-southeast of El Paso. These quartz geodes, also known as coconut agates, are mined from a 2-square-mile area and have constituted a multi-million dollar business. The deposit was discovered by Ramon Peña in 1961, but it wasn't until 1965 that production finally reached the market. Mineral dealer Jack Young recalls how surprised he and the other El Paso dealers were to see the geodes introduced for the first time

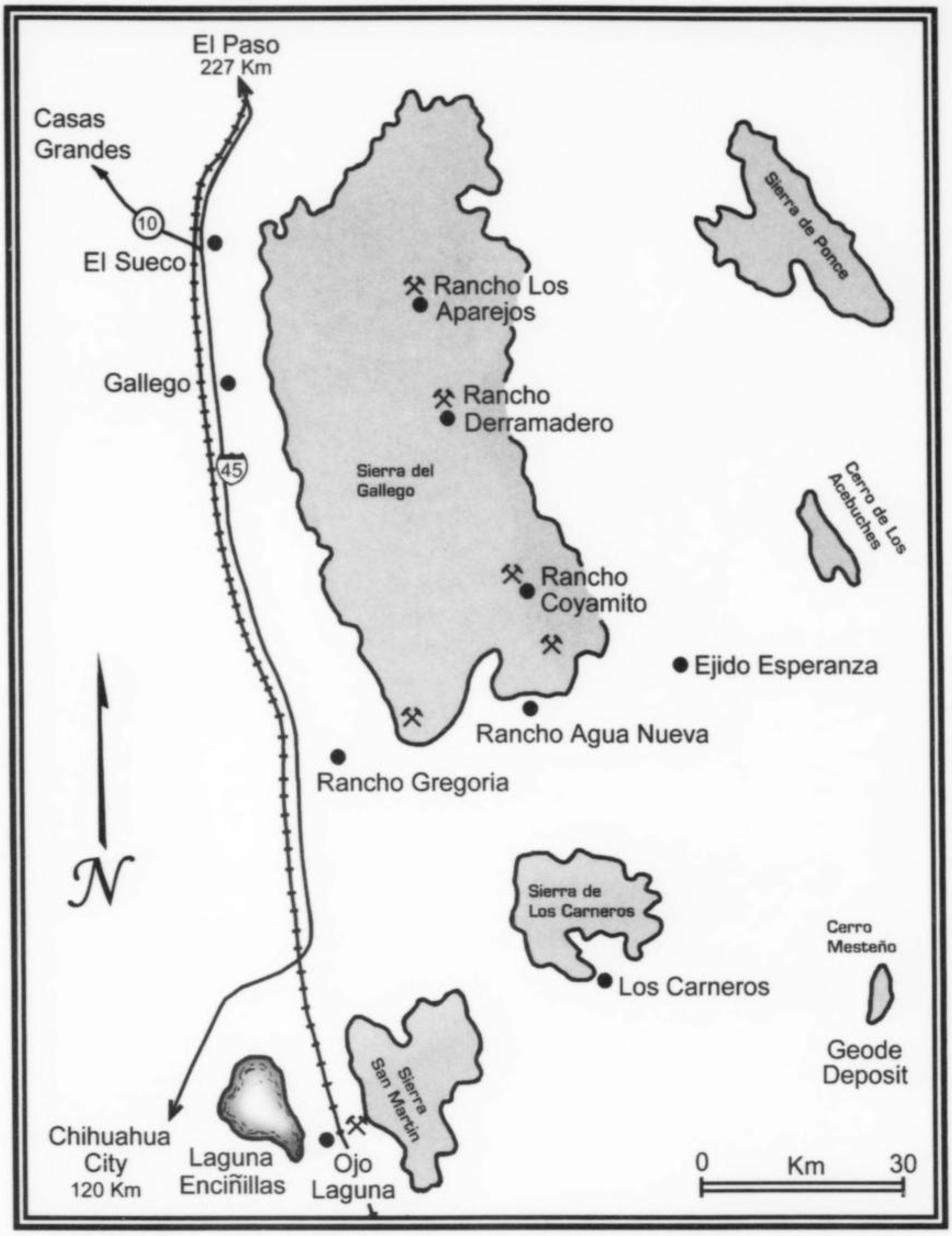


***Figure 2.* Agate occurrences in the Sierra del Gallego area, Chihuahua, Mexico.**

at the 1965 Phoenix Gem and Mineral Show. Certainly a discovery of this magnitude couldn't have escaped their notice in El Paso!

Production records have never been kept; however, it is estimated that over 150,000 pounds of coconuts per year are mined from these claims. Although this production may seem quite high, only 20% of the nodules mined prove to have the desirable hollow centers.

The geodes occur as spherical cavity fillings in an intensely altered, feldspar-rich ash flow tuff. The producing unit is locally known as the Liebres Formation and is about 44 million years old, making it one of the oldest volcanic units in the agate-producing region.

Because of the westerly dip of the geode-containing formation, current mine shafts reach depths of up to 200 feet. All mining activity is conducted on ranchland owned by Hector and Jeannette Carrillo of *Gem Center, USA* in El Paso, Texas.

The geodes commonly have a blue-gray chalcedony or siderite lining that grades inward into well-defined crystalline quartz with discrete crystals whose apices point toward the center of the geode. Varieties of quartz found within the geodes range from clear to smoky to amethystine, and over 18 different microscopic minerals have been identified within the geodes (Keller 1977). Other secondary mineralization includes several varieties of calcite as well as a number of zeolite minerals.

Loma Pinta Agate

Loma Pinta ("Painted Hill") nodules are found on the southeastern flank of Cerro Brajo de Diablo ("Devil's Needle Mountain"), some 15 miles east of Estación Moctezuma. The name "Loma Pinta" was given to the agate by Dr. I. M. Epstein, an El Paso pediatrician and agate collector, in the 1950s and 1960s.

Loma Pinta agates typically exhibit grayish shades and tints of pink, pale orange, pale yellow and red. The banding tends to be comparatively shallow and irregular. The nodules are generally spherical, and the outer coating or rind is typically very smooth and is reddish brown to green.

The agate was initially mined by Tomas Saenz (of Ciudad Juárez)

(Text continued on p. 87)

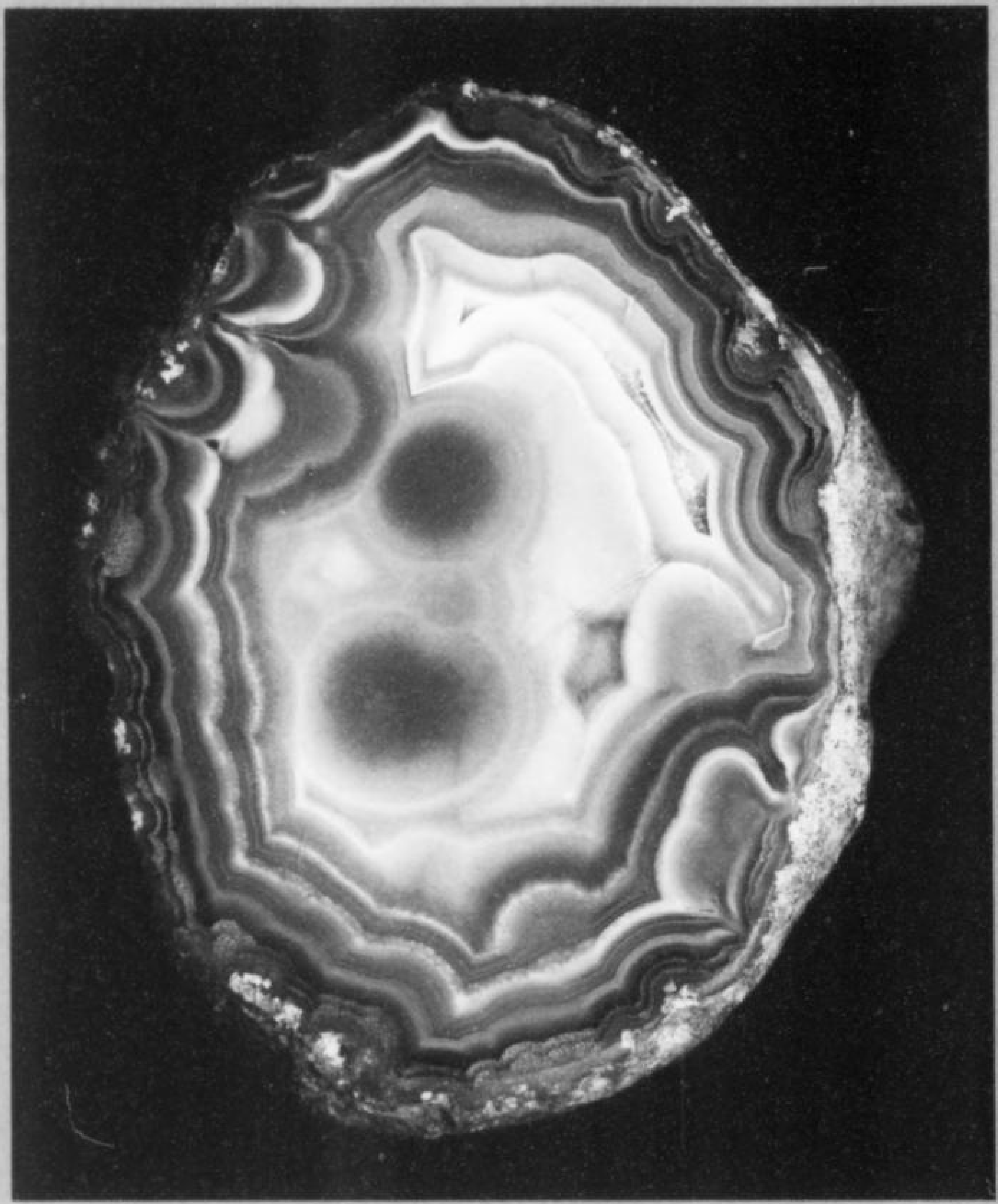
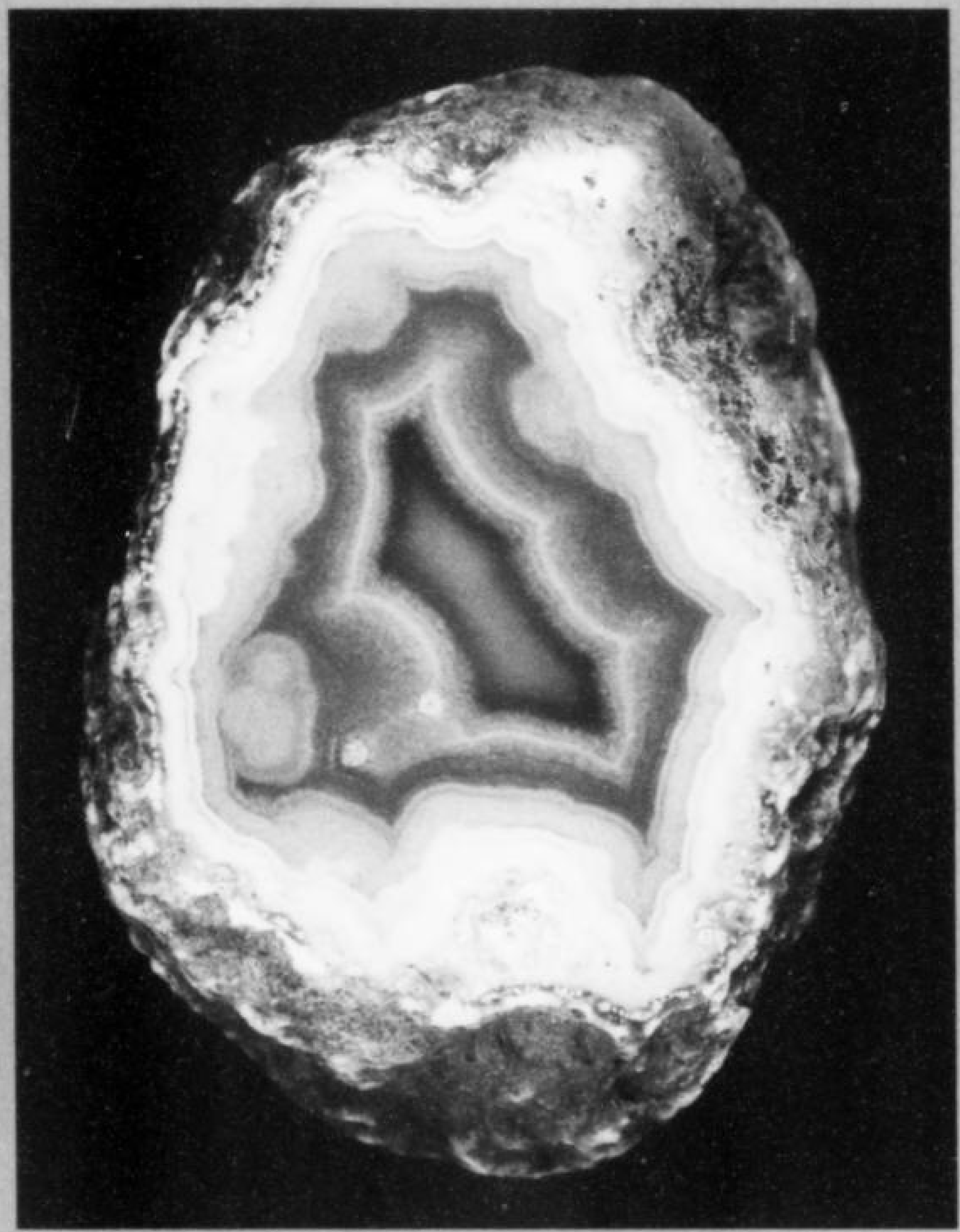


Figure 3. **Carneros agate, 6.1 cm, from the Sierra de los Carneros, Chihuahua. Brad Cross collection; Wendell Wilson photo.**

Figure 4. **Coyamito agate, 3.8 cm, from Rancho Coyamito Norte, Chihuahua. Brad Cross specimen and photo.**



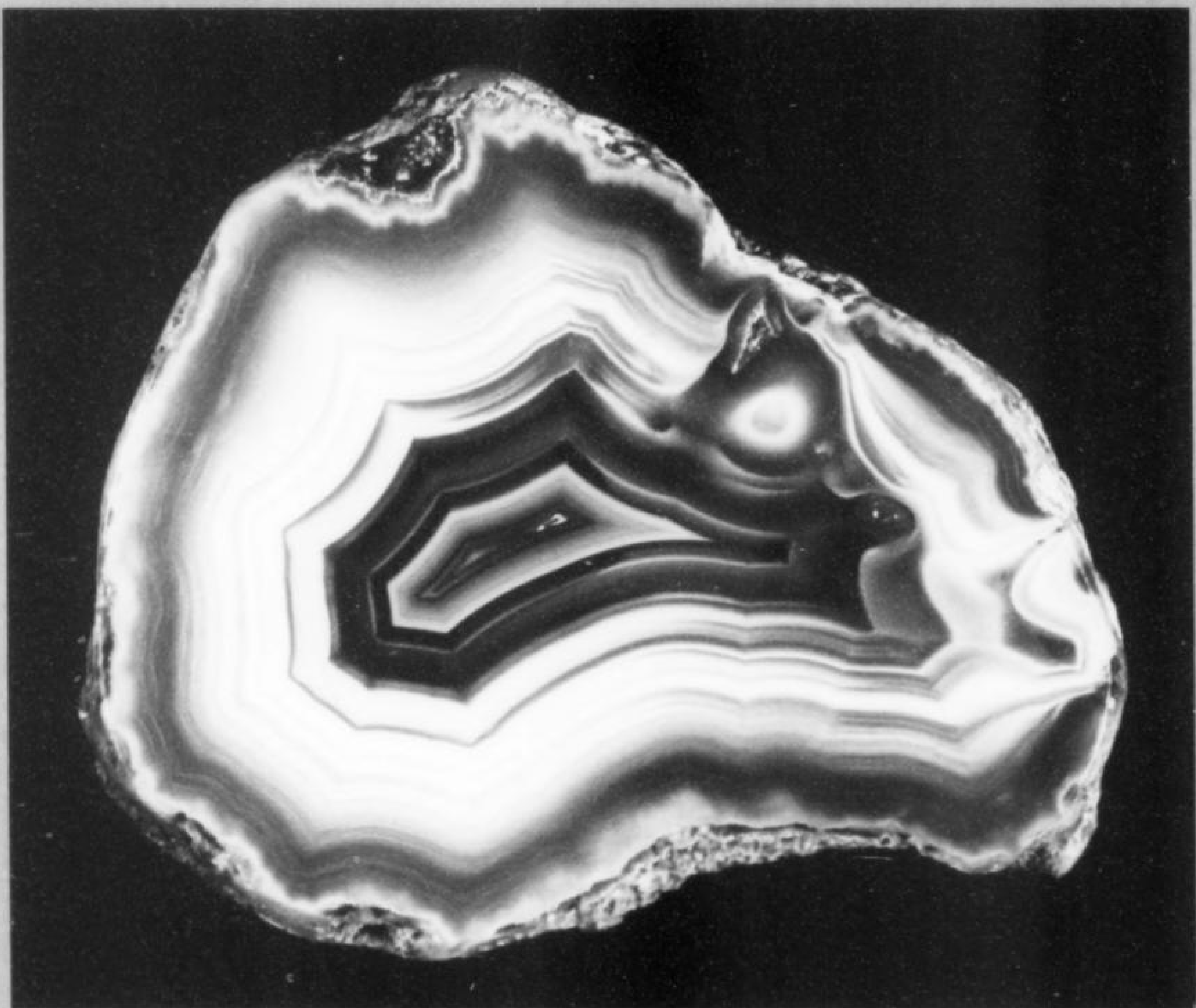


Figure 5. **Aparejos agate, 10.2 cm, from Rancho Los Aparejos, Chihuahua. Brad Cross specimen and photo.**

Figure 7. **Snowball agate, 5 cm, from south of Samalayuca, Chihuahua. Brad Cross collection; Wendell Wilson photo.**

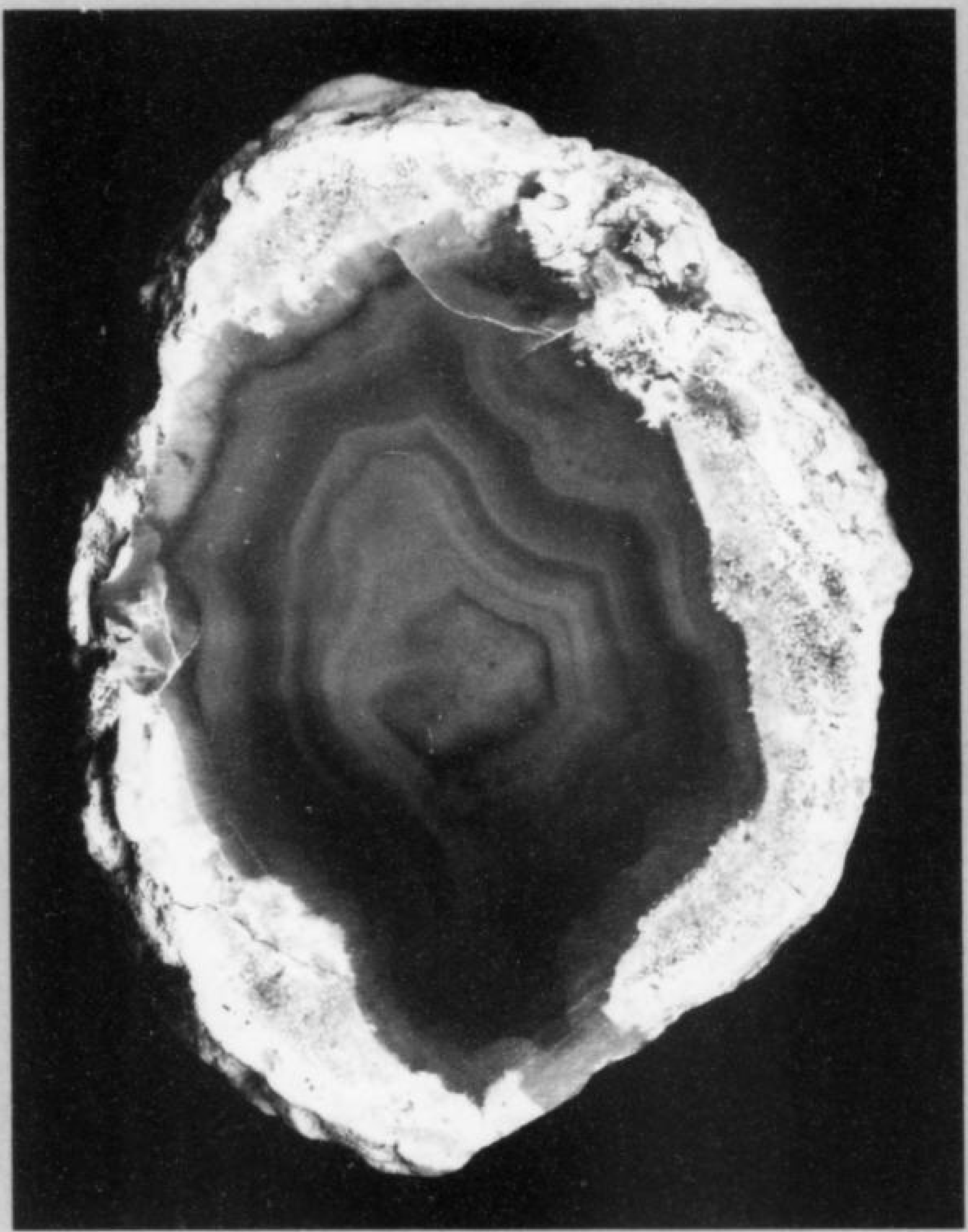


Figure 6. **Sueco agate, 5 cm, from Rancho El Sueco, Chihuahua. Brad Cross specimen and photo.**

Figure 8. **Derramadero agate, 7.4 cm, from Rancho Derramadero, Chihuahua. Brad Cross collection; Wendell Wilson photo.**

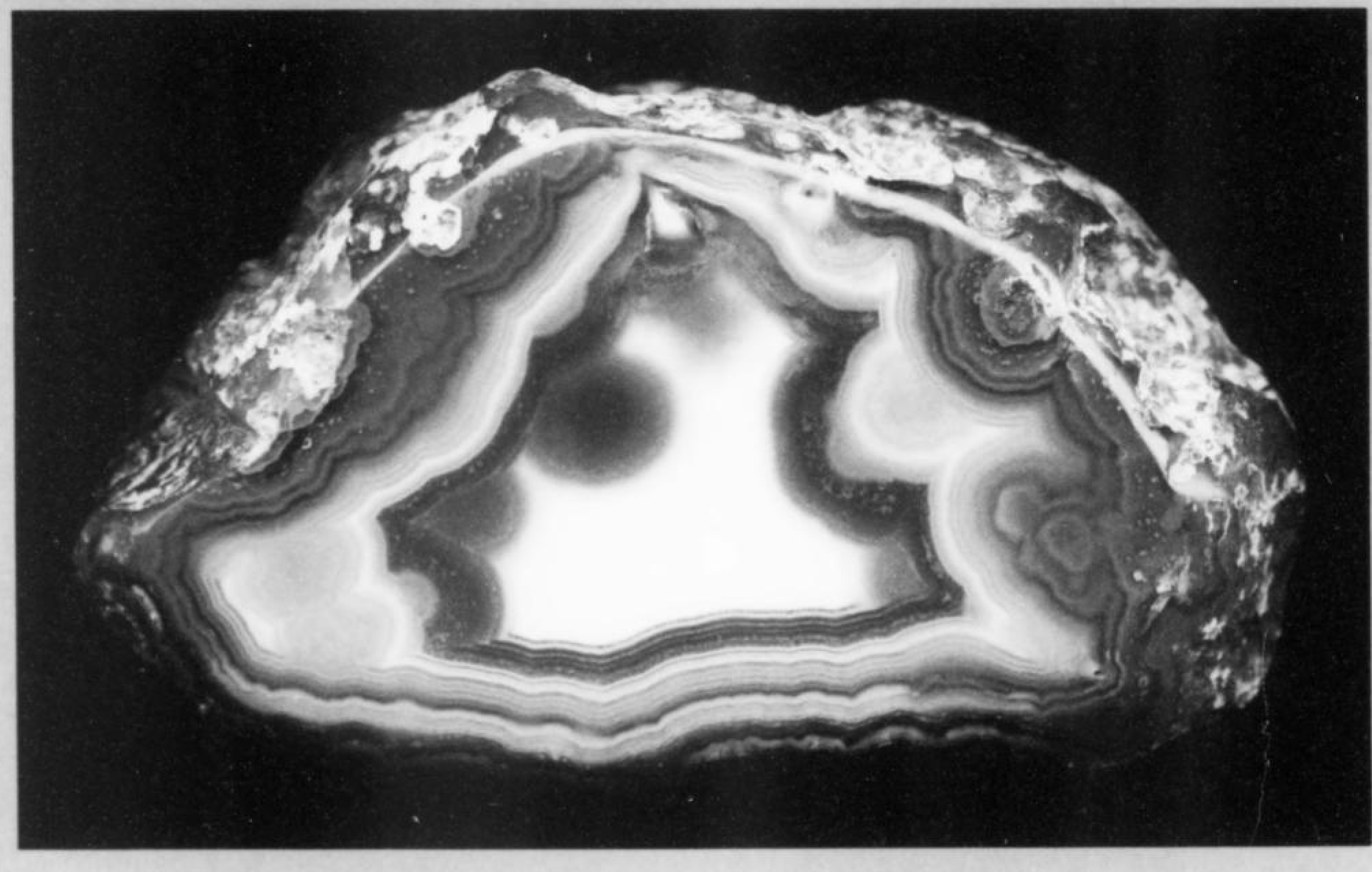
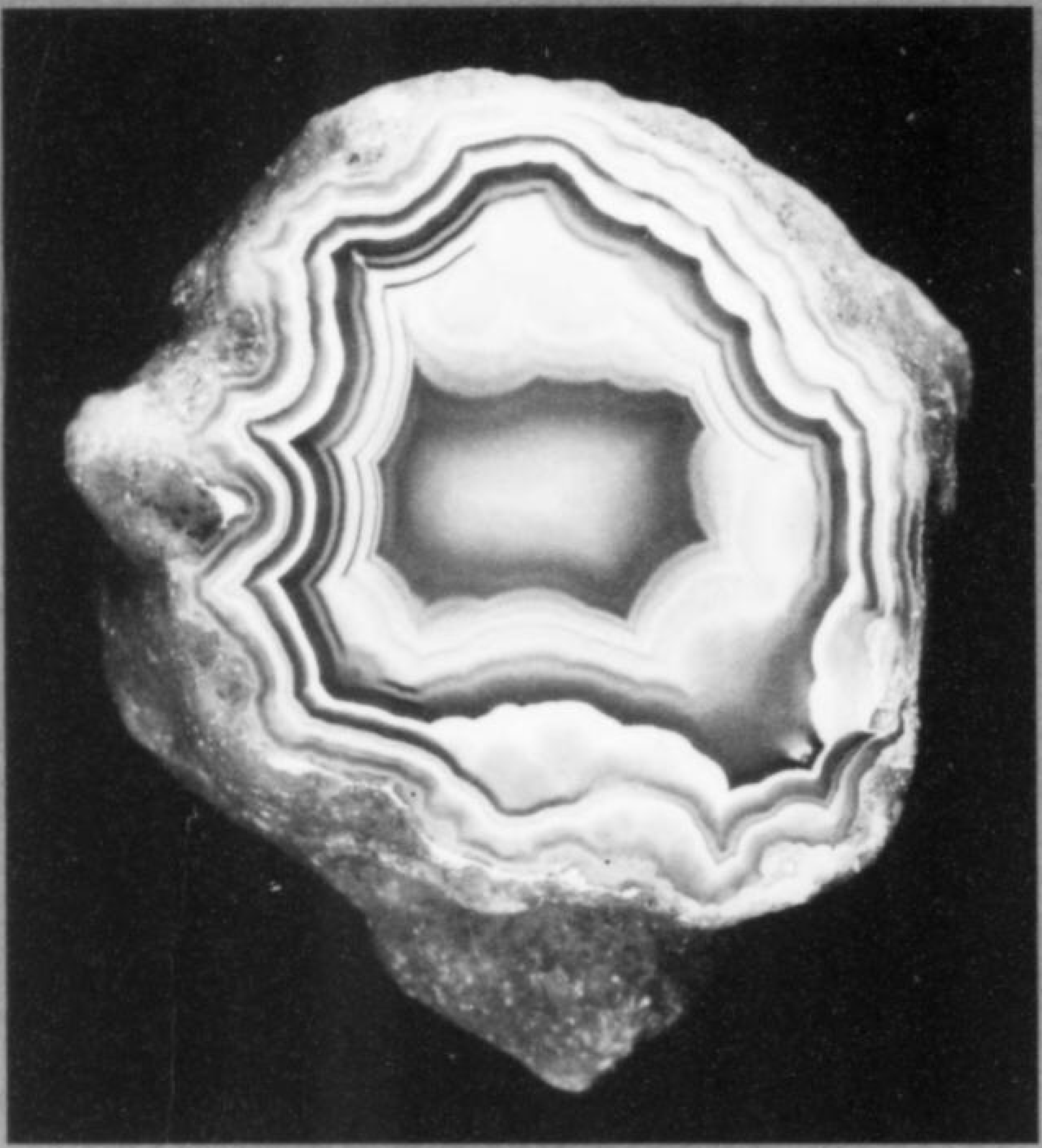


Figure 9. Coyamito agate, 5 cm, from Rancho Coyamito Norte, Chihuahua, Mexico. Brad Cross specimen and photo.



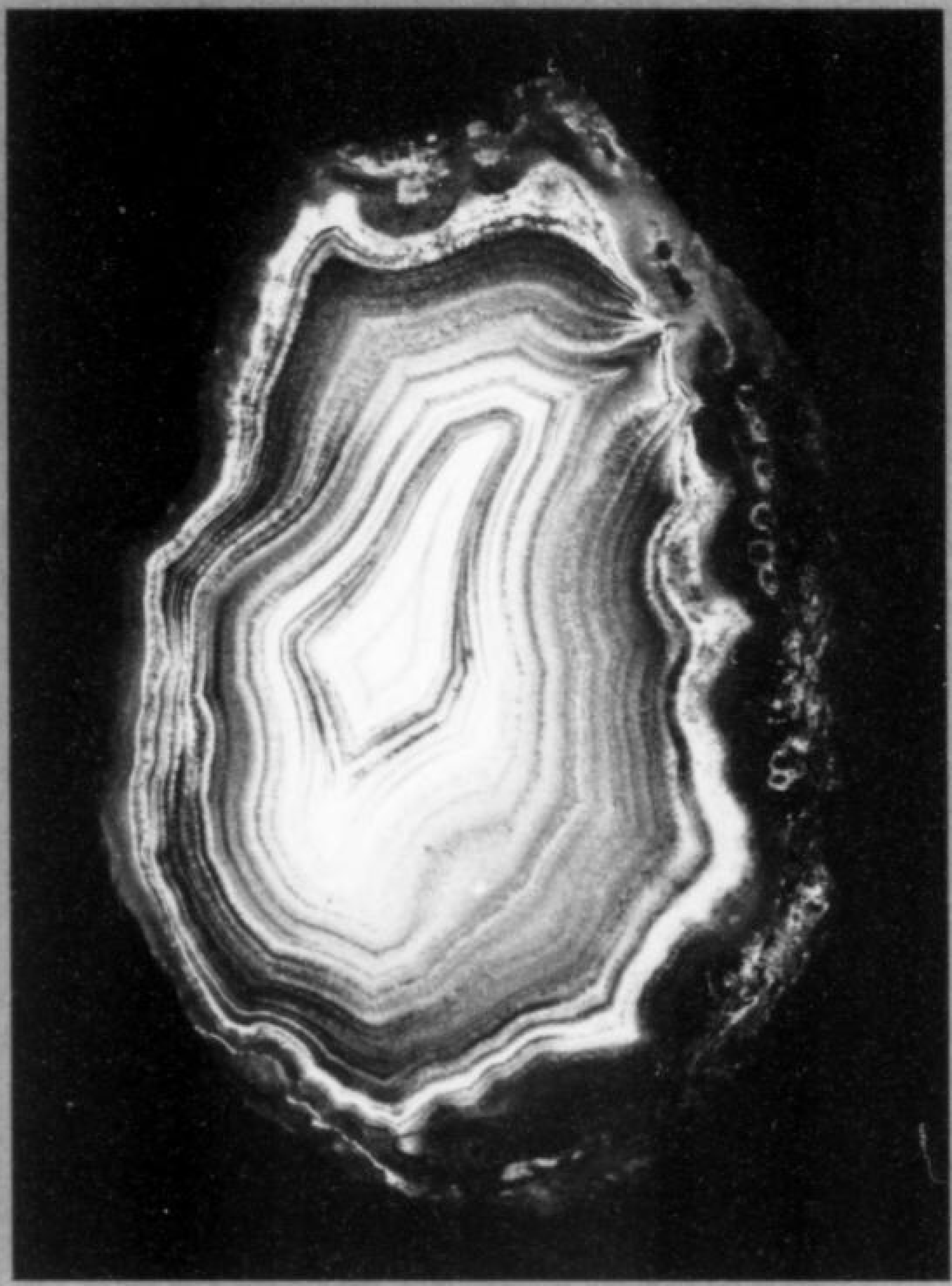


Figure 10. Casas Grandes agate, 5.7 cm, from Rancho Colorado, Chihuahua. Brad Cross specimen and photo.

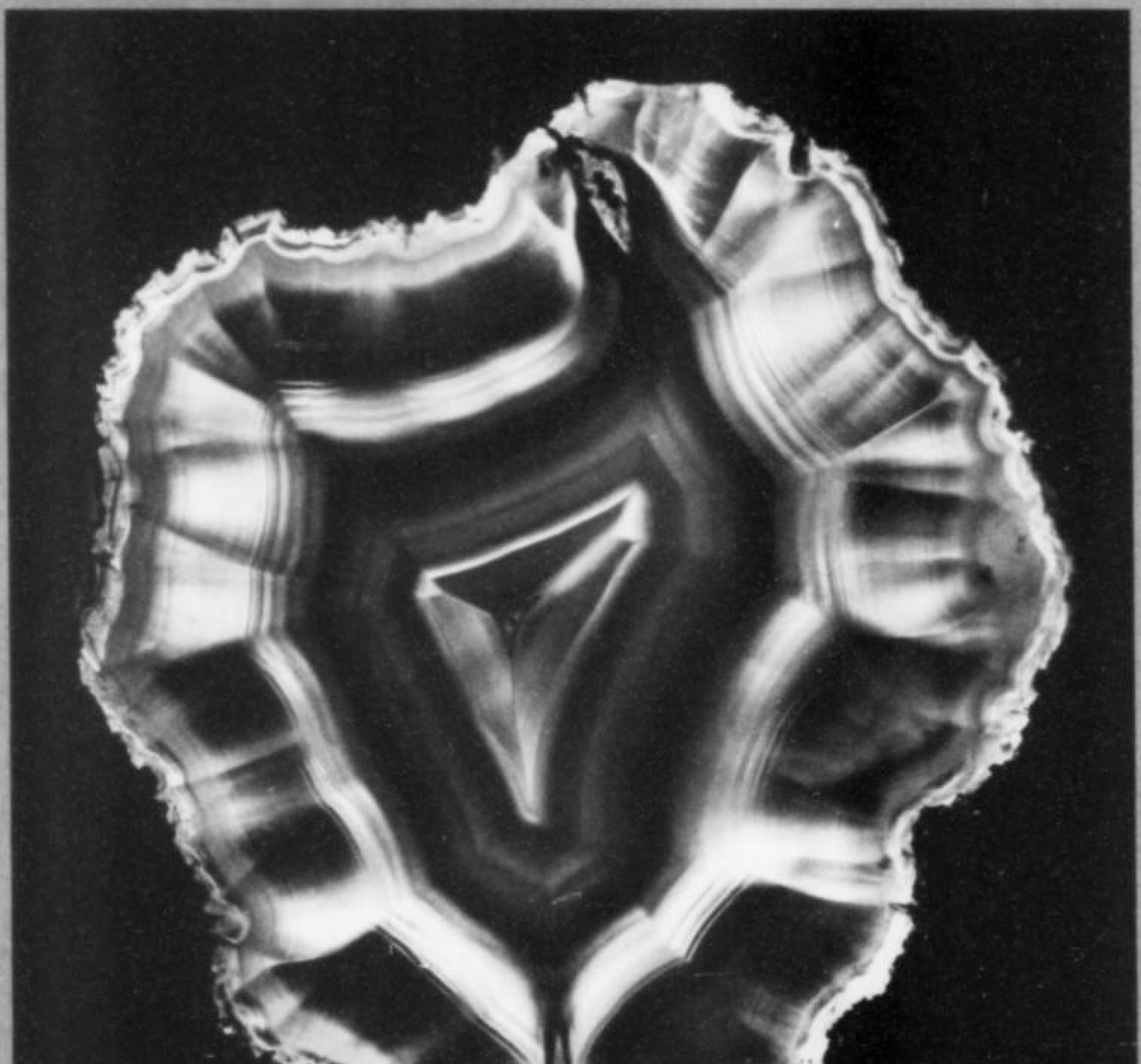


Figure 11. Gallego agate, 6.4 cm, from Rancho Gallego, Chihuahua. This specimen shows an iris effect. Brad Cross specimen and photo.

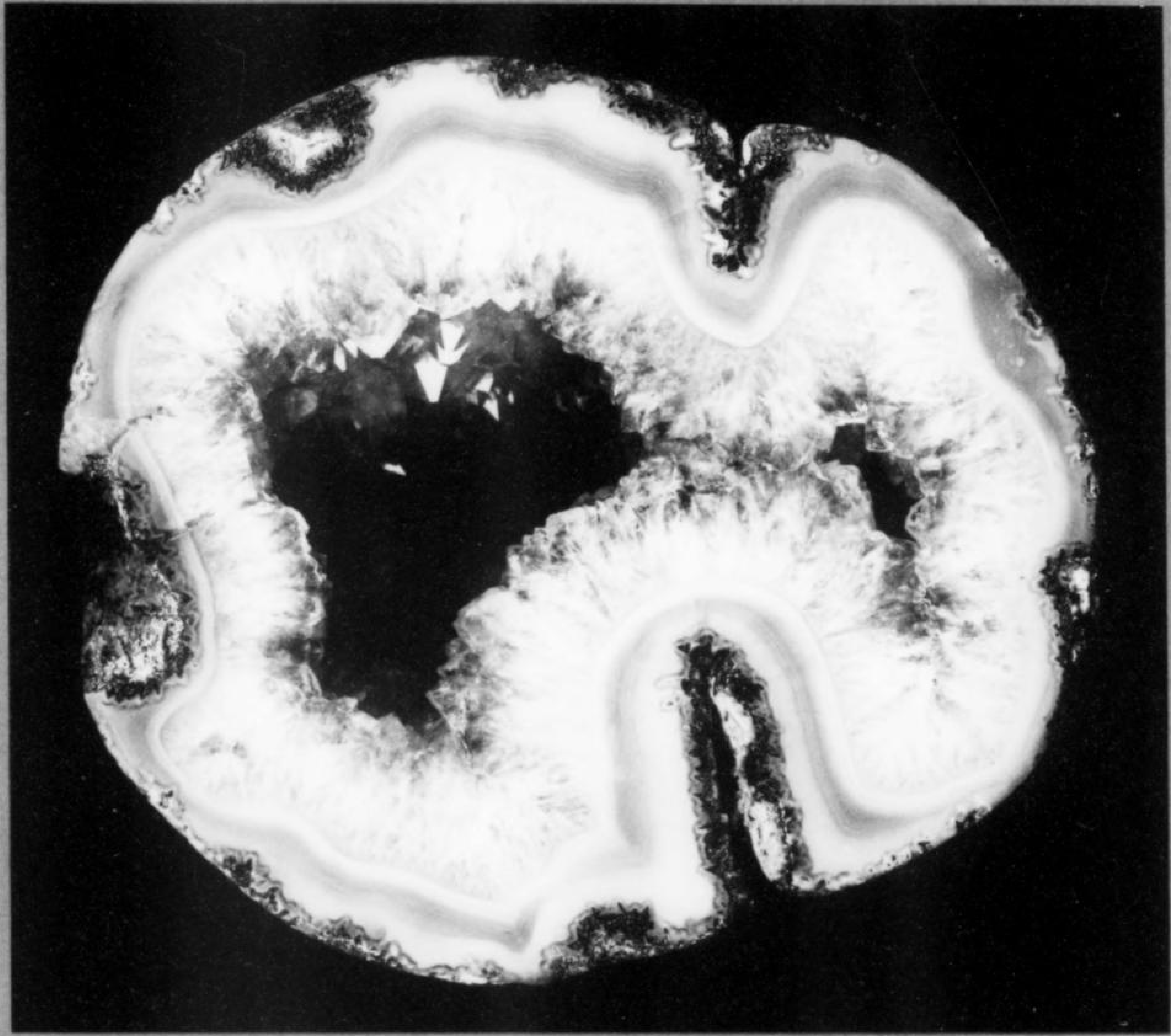


Figure 12. Las Choyas agate/ amethyst geode, 17.3 cm, from near Laguna Enciñillas, Chihuahua. Wendell Wilson collection and photo.

Figure 13. Parcelas agate, 5 cm, from Cerro El Oregano, Chihuahua. Brad Cross specimen and photo.

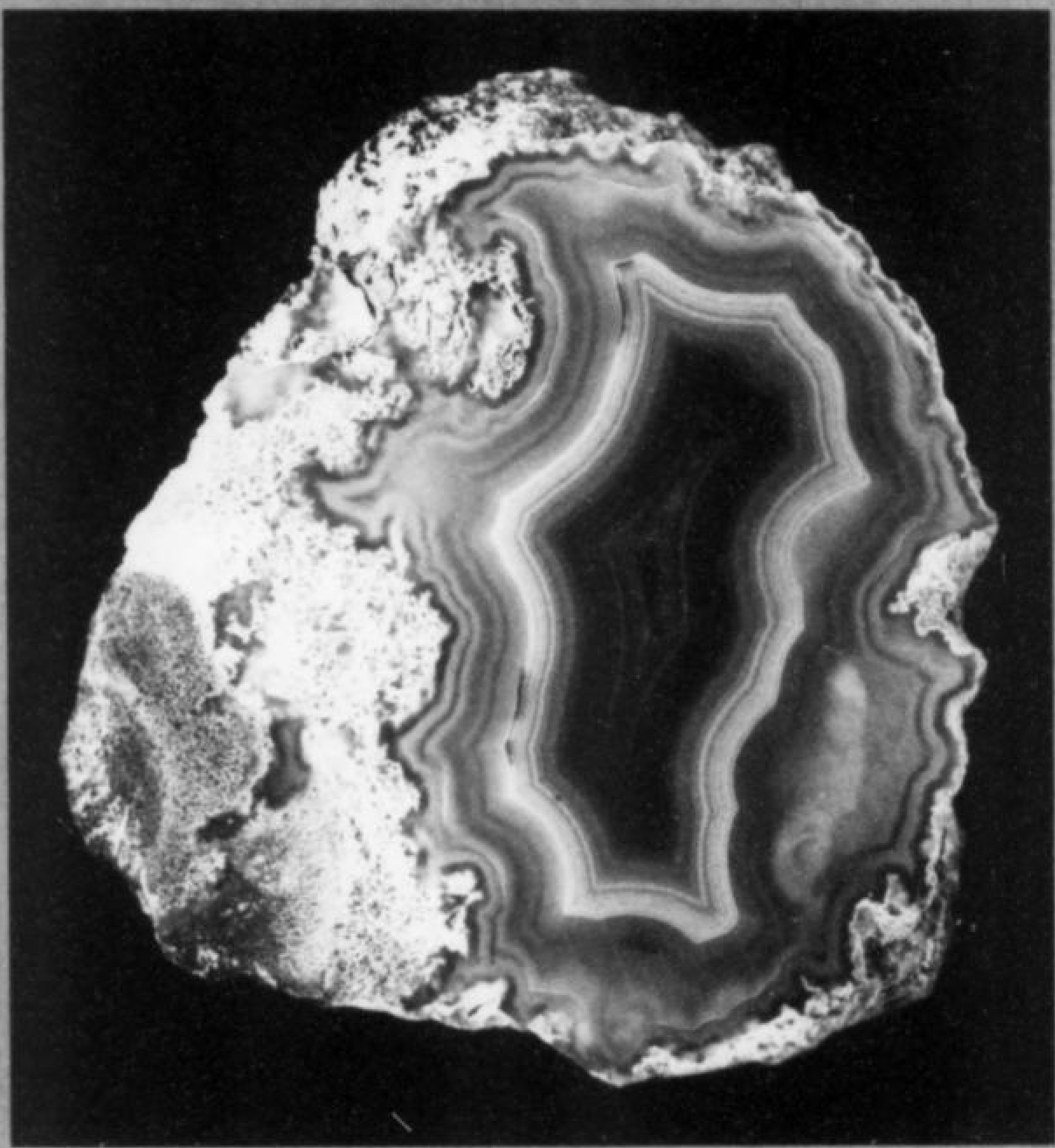


Figure 14. Coyamito agate, 12.9 cm, from Rancho Coyamito Norte, Chihuahua. David Wilber collection; Jeff Scovil photo.

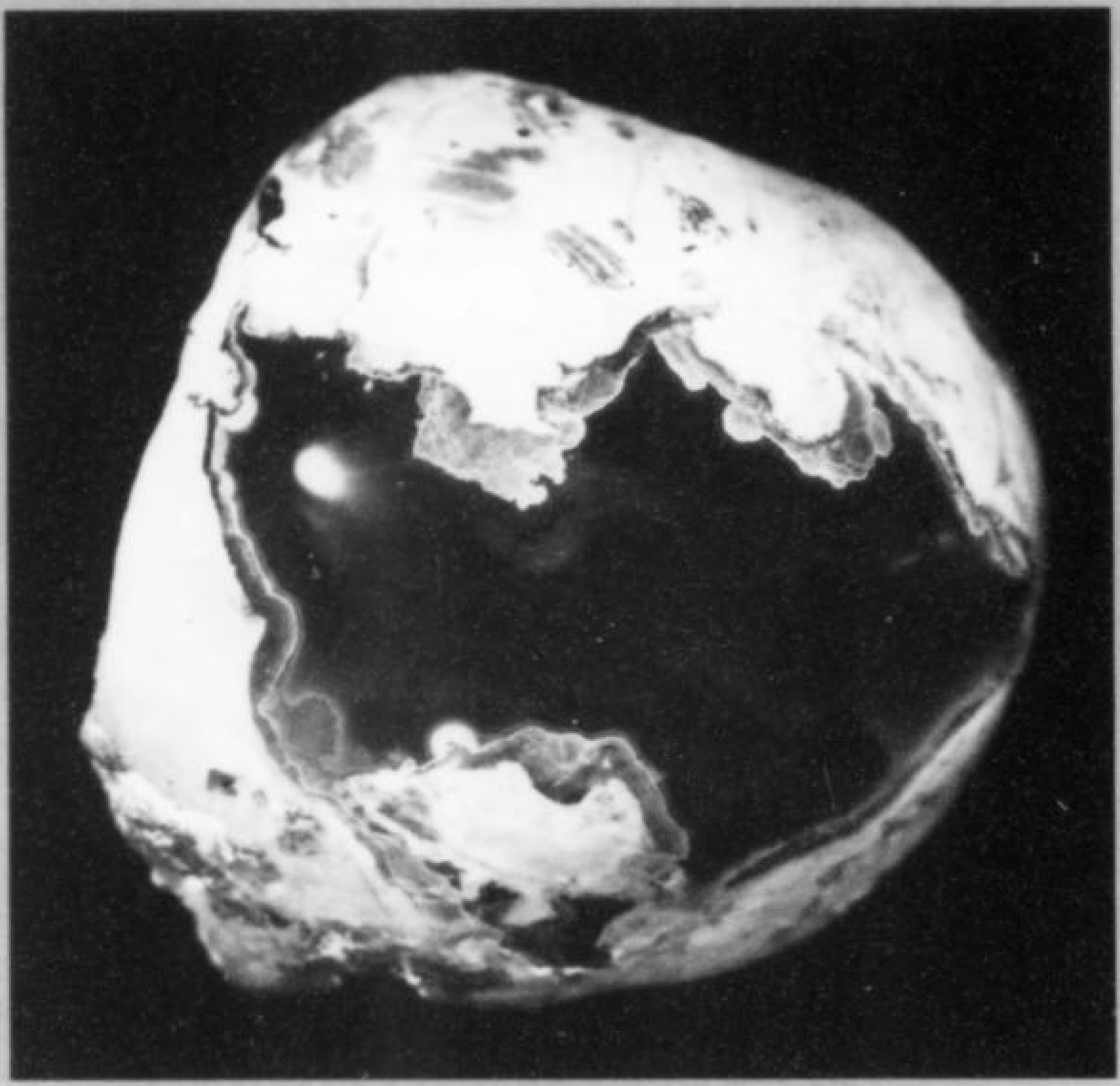


Figure 15. Blue chalcedony, 6.9 cm, from west of Villa Ahumada, Chihuahua. Brad Cross collection; Wendell Wilson photo.

Figure 16. Pseudomorph of agate after pseudohexagonally twinned aragonite, 8.9 cm, from Rancho Coyamito Norte, Chihuahua. Brad Cross specimen and photo.

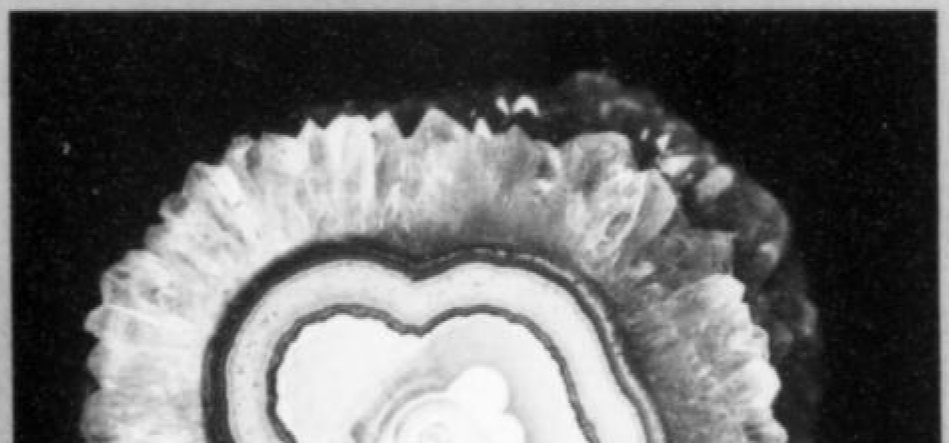


Figure 18. Santa Gertrudis agate, 4.9 cm, Brad Cross collection; Wendell Wilson photo.

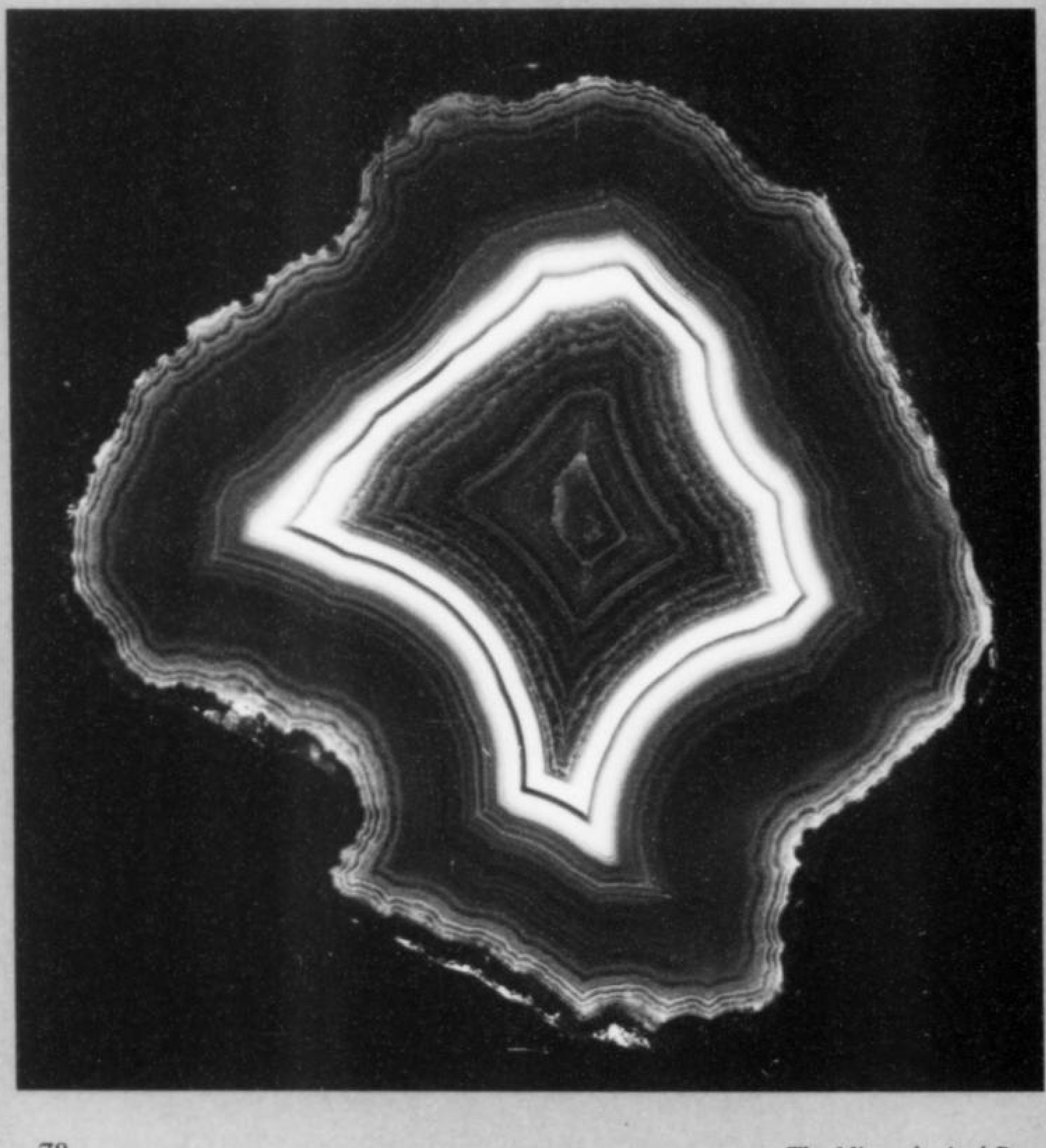


Figure 17. Gregoria agate, 6.4 cm, from Rancho La Gregoria, Chihuahua. Brad Cross specimen and photo.

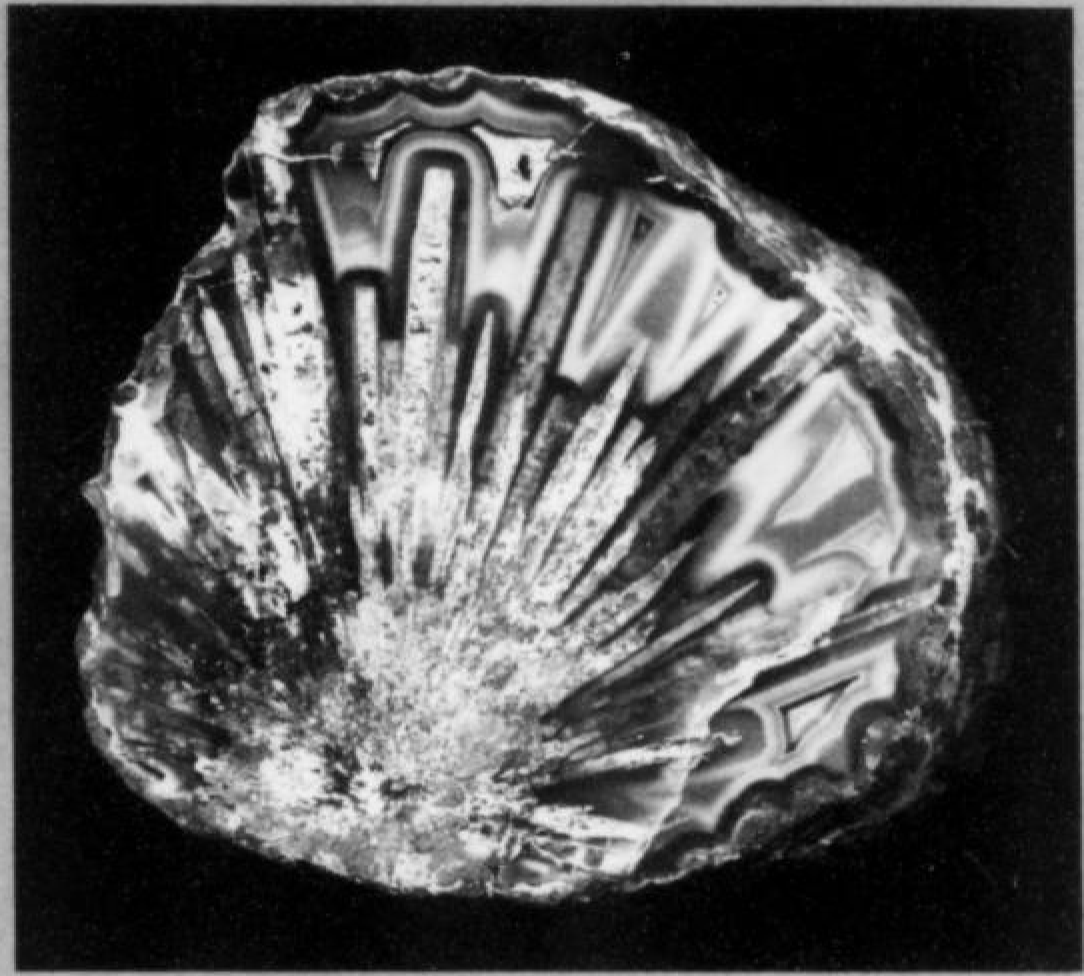


Figure 19. **Sagenite agate, 8.9 cm, Brad Cross collection; Wendell Wilson photo.**

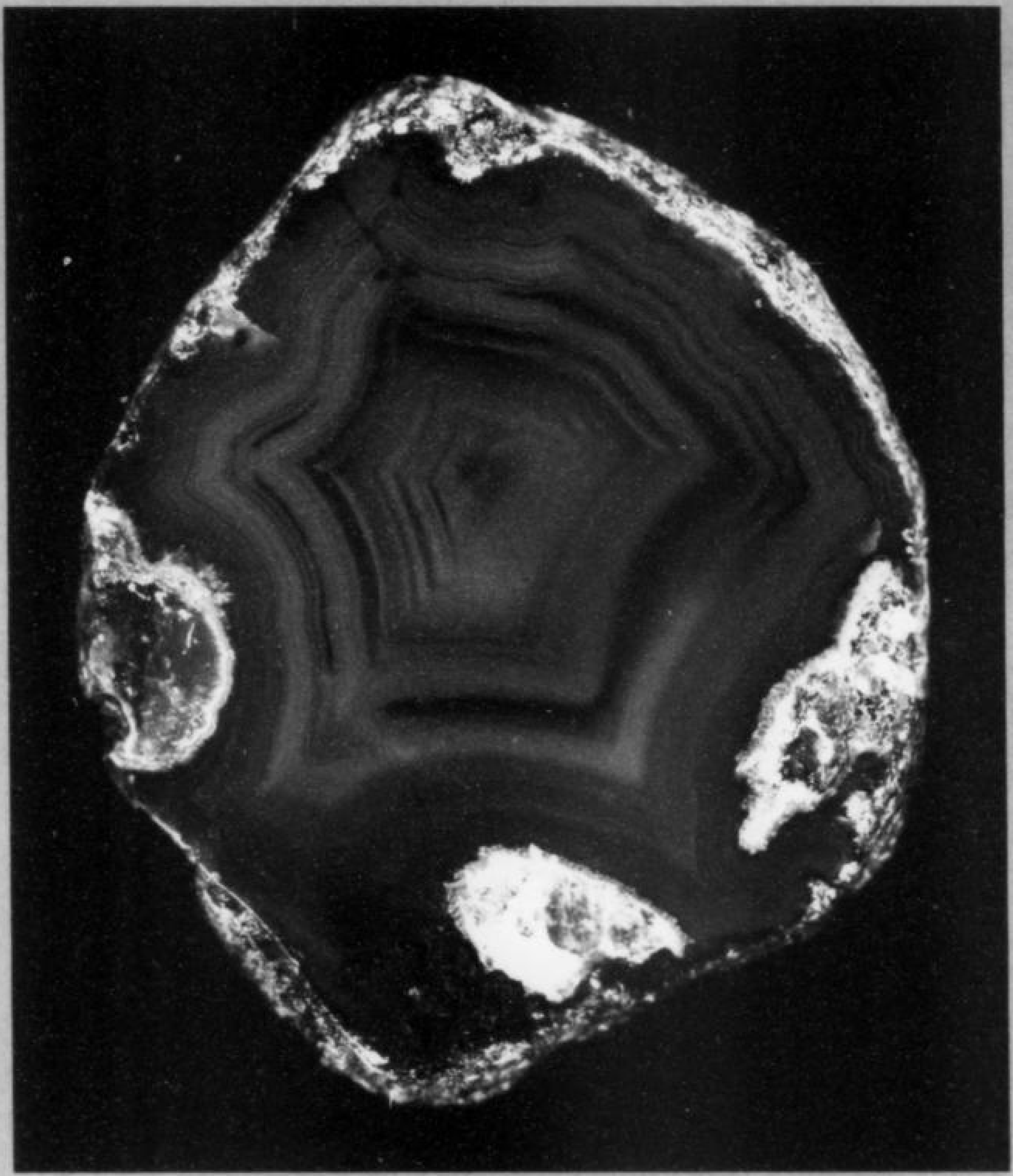
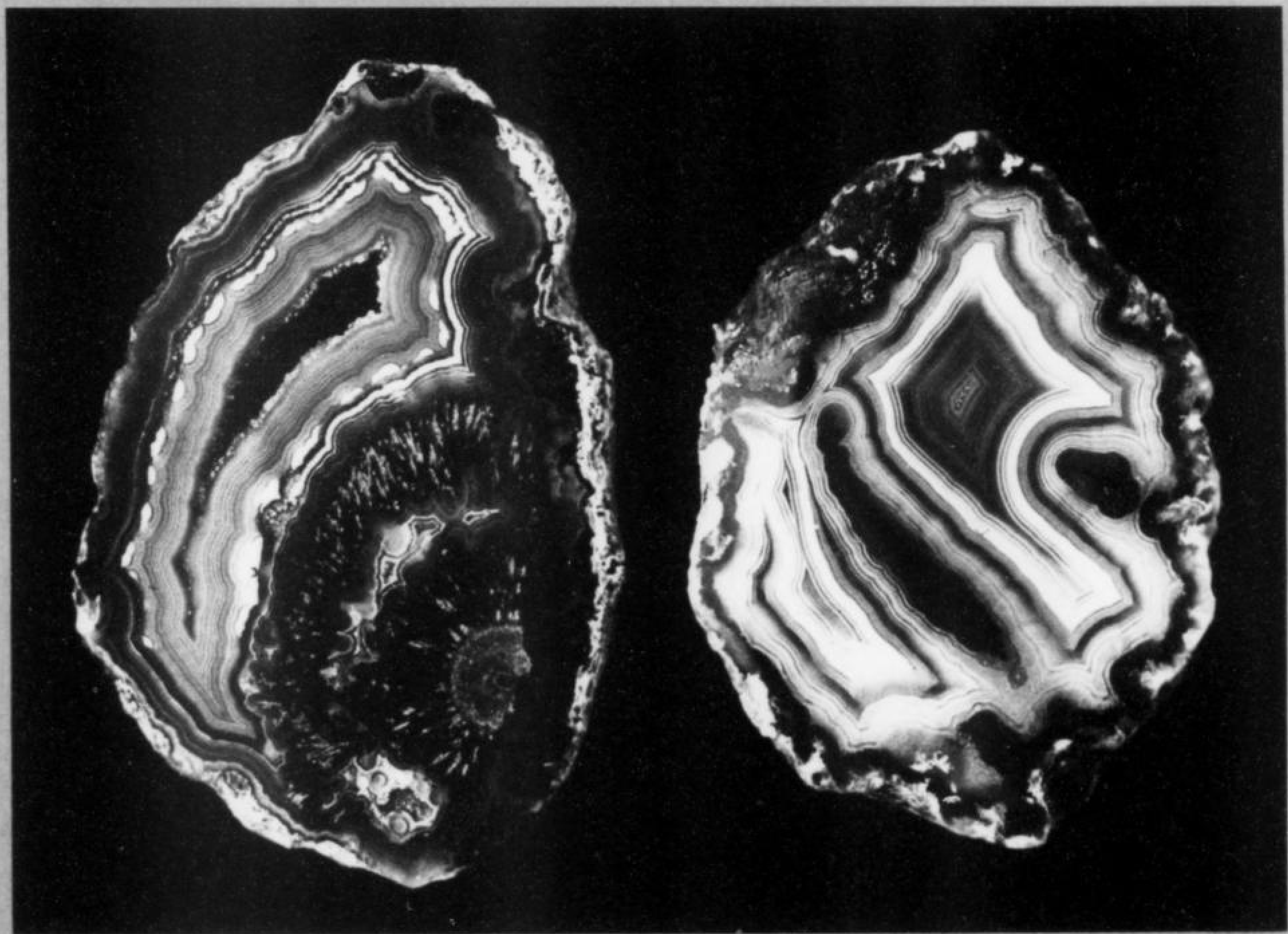


Figure 20. **Agua Nueva agate, 5 cm, from Rancho Los Nogales, Chihuahua. Brad Cross specimen and photo.**

Figure 21. **Laguna agates, 6.3 cm and 7.3 cm, from east of Estación Ojo Laguna, Chihuahua. David Wilber collection; Jeff Scovil photo.**



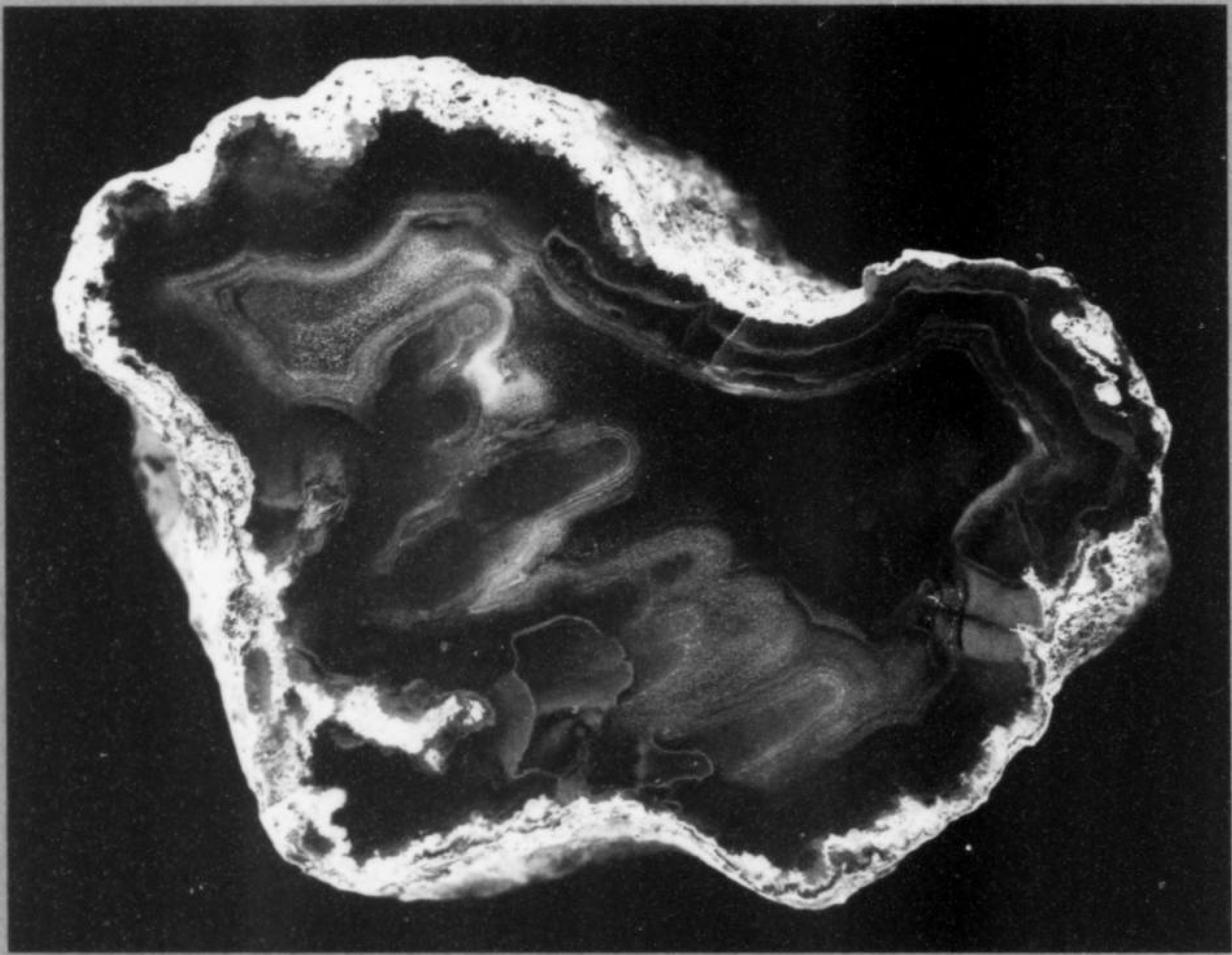
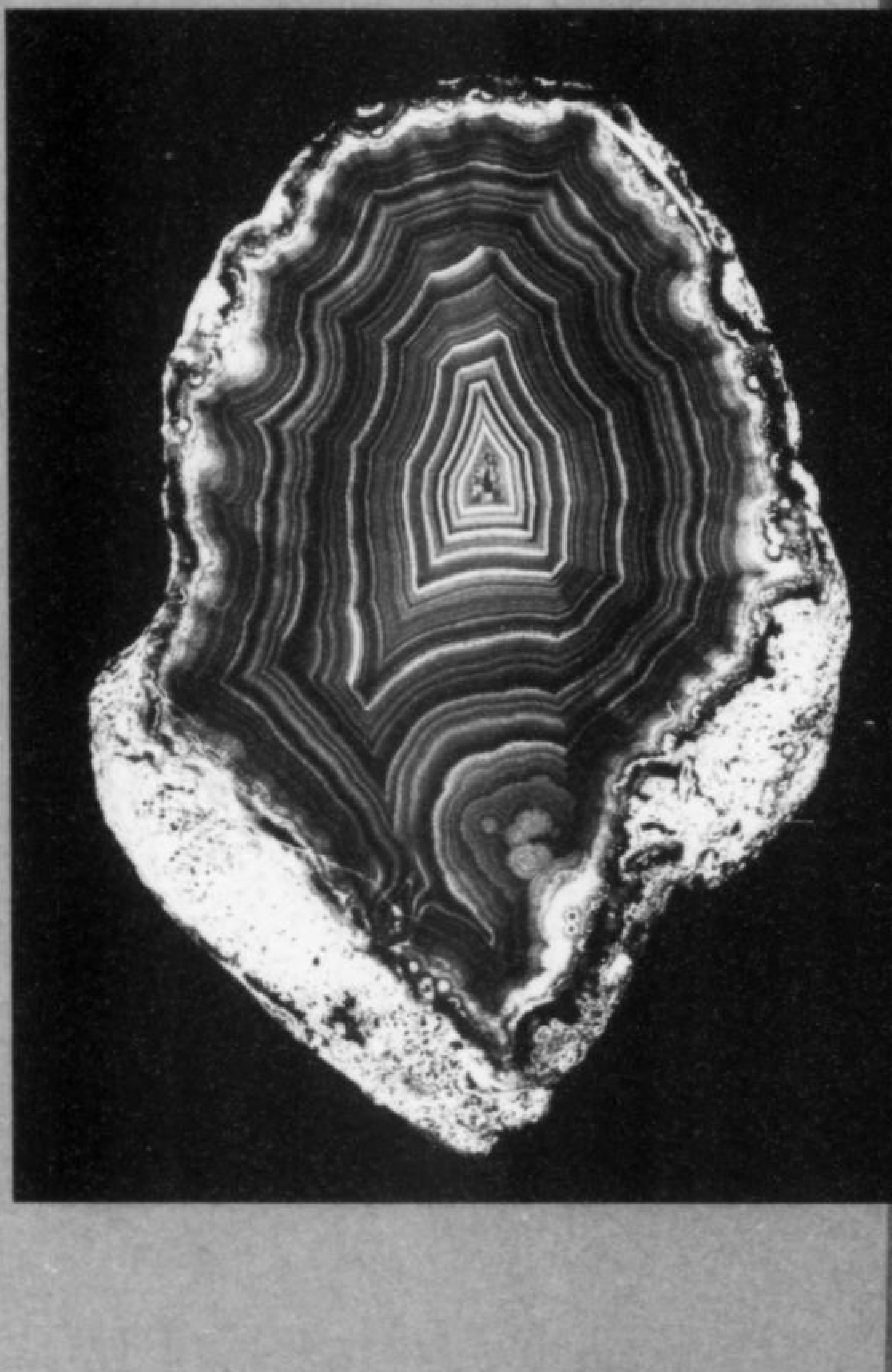


Figure 22. **Apache agate, 9.9 cm, from Rancho la Viñata, Chihuahua. David Wilber collection; Jeff Scovil photo.**

Figure 23. **Moctezuma agate, 7.6 cm, from Rancho Barreal, Chihuahua. This specimen is known to agate aficionados as "Mother Goose." Brad Cross specimen and photo.**

Figure 24. **Laguna agate, 7.6 cm, from east of Estación Ojo Laguna, Chihuahua. Brad Cross collection and photo.**



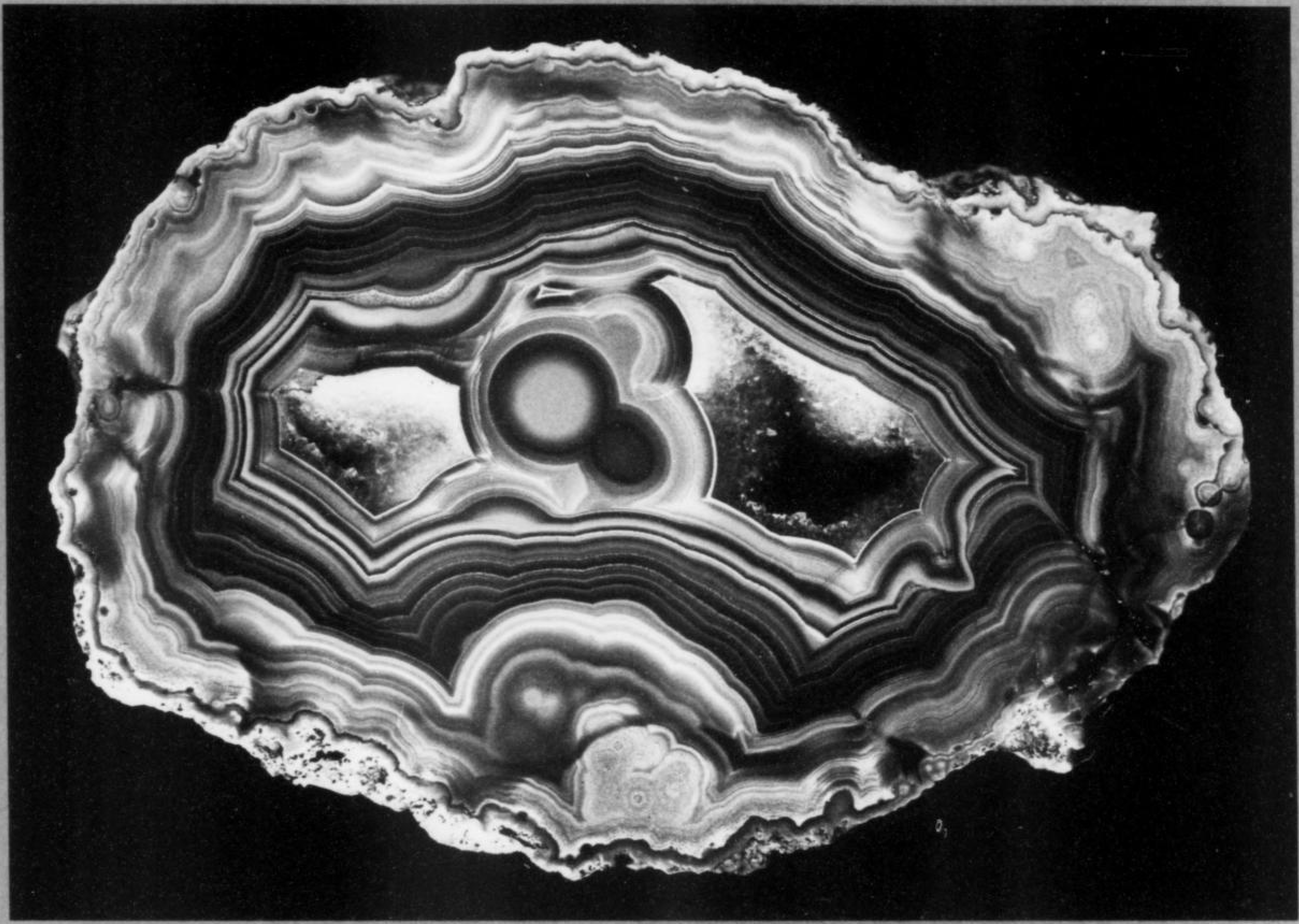


Figure 25. Laguna agate, 15.2 cm, from east of Estación Ojo Laguna, Chihuahua. David Wilber collection; Jeff Scovil photo.

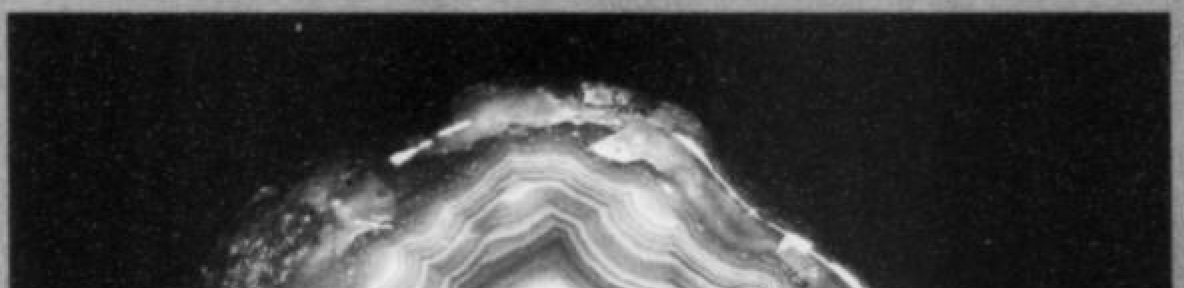


Figure 26. Laguna agate, 10.2 cm × 7.6 cm, from east of Estación Ojo Laguna, Chihuahua. Brad Cross specimen and photo.

Figure 27. Laguna agate, 7.3 cm, from east of Estación Ojo Laguna, Chihuahua. David Wilber collection; Jeff Scovil photo.

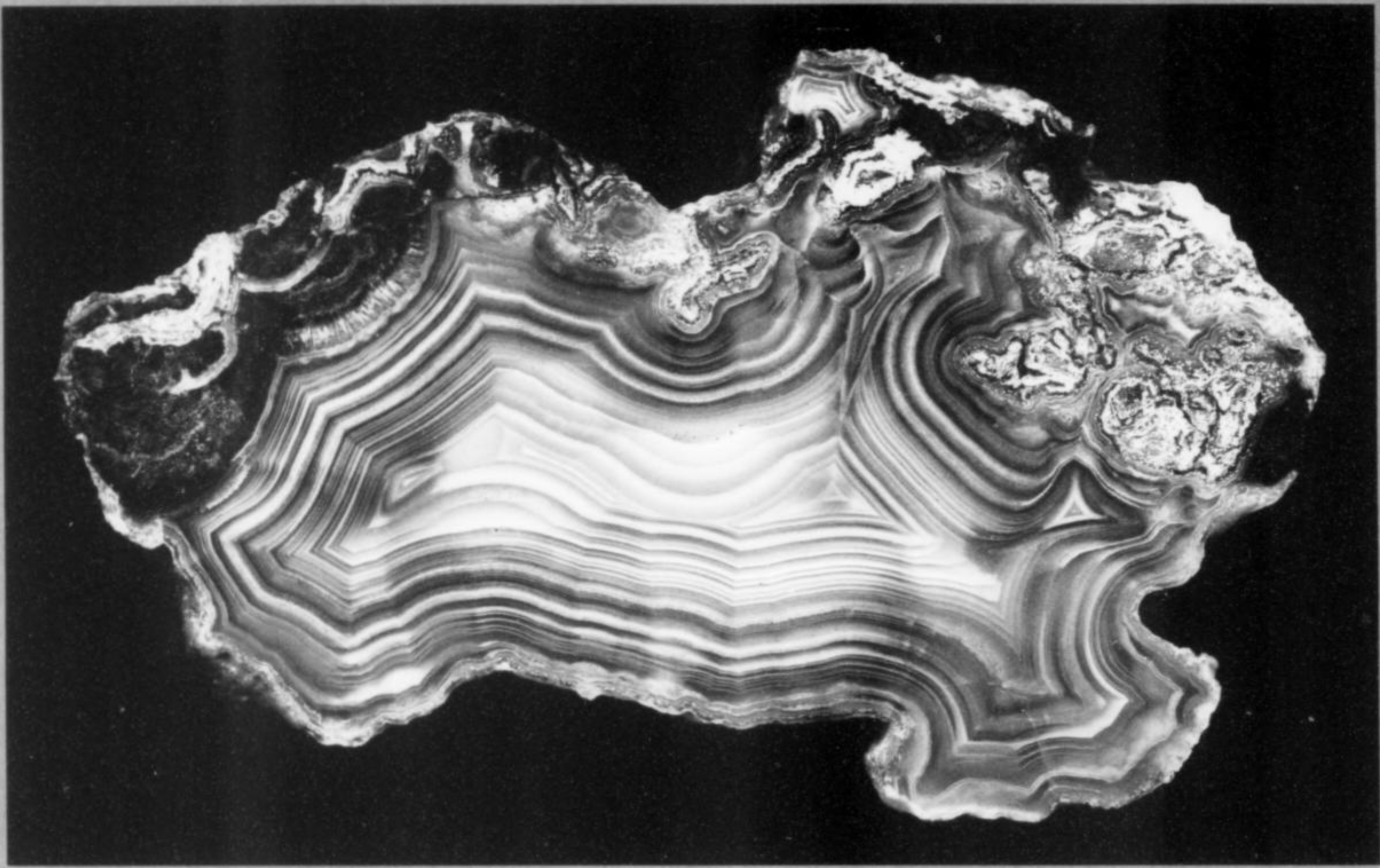


Figure 28. **Laguna agate, 10.3 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**

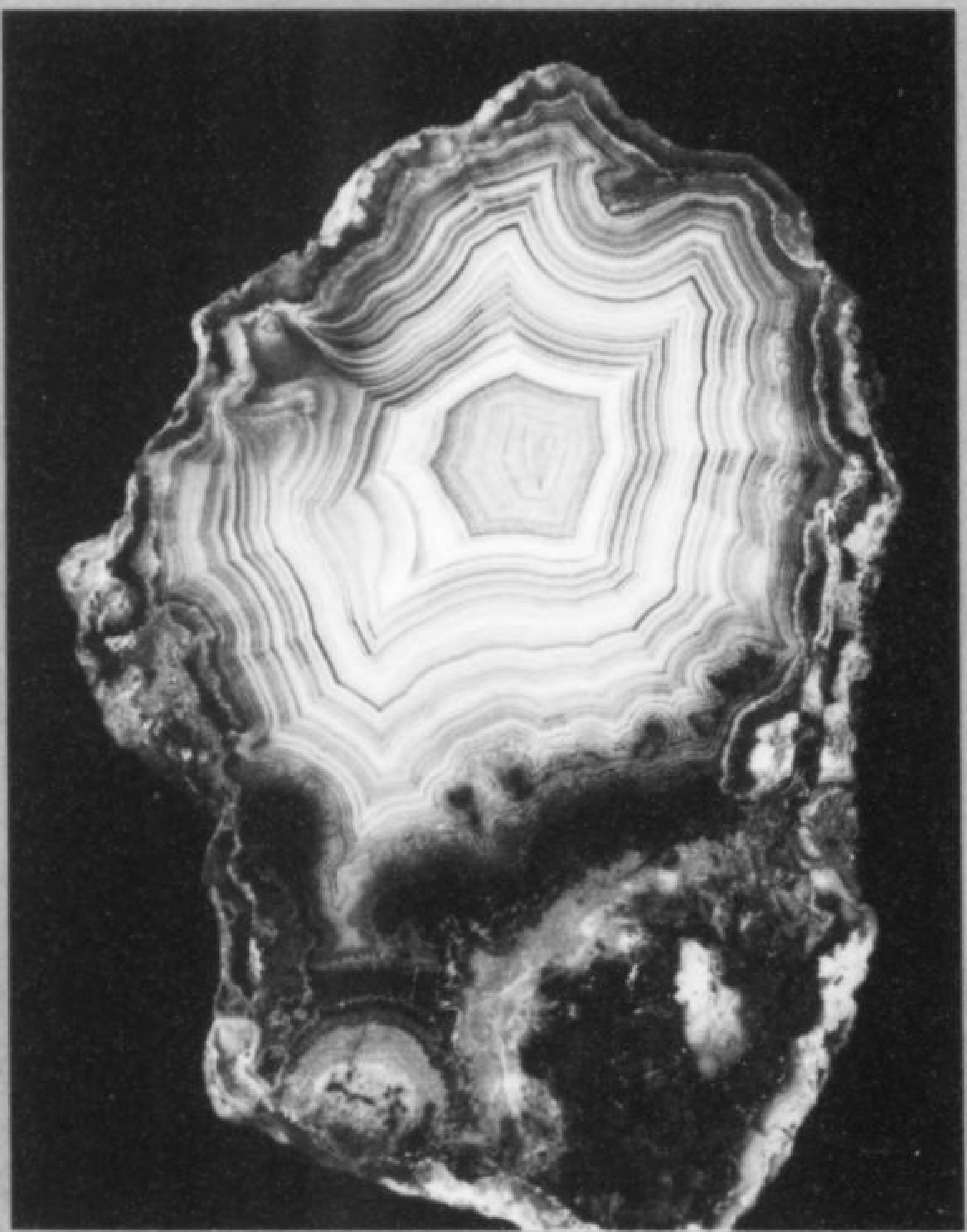


Figure 29. **Laguna agate, 7.3 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**

Figure 30. **Laguna agate, 6.6 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**

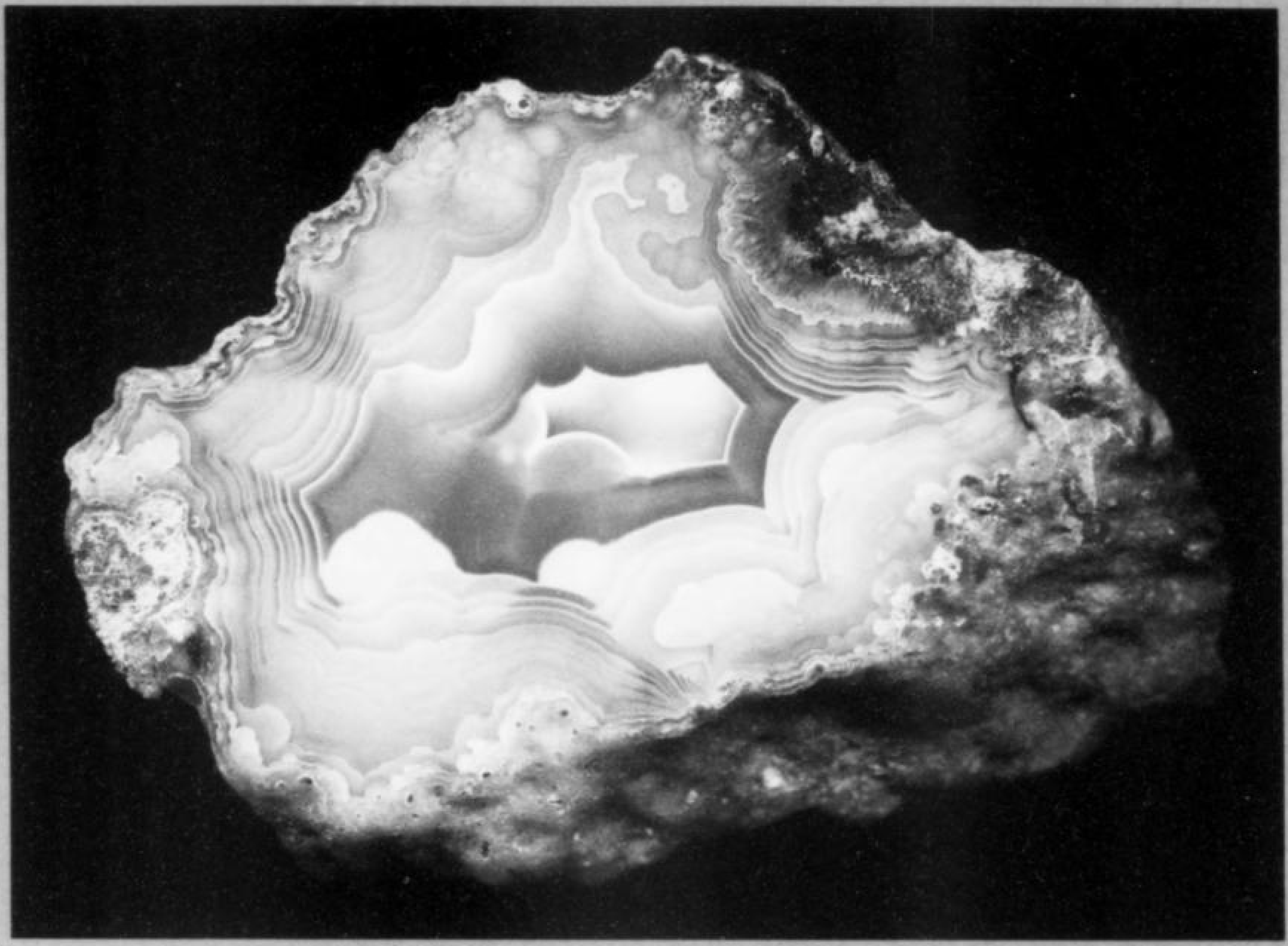
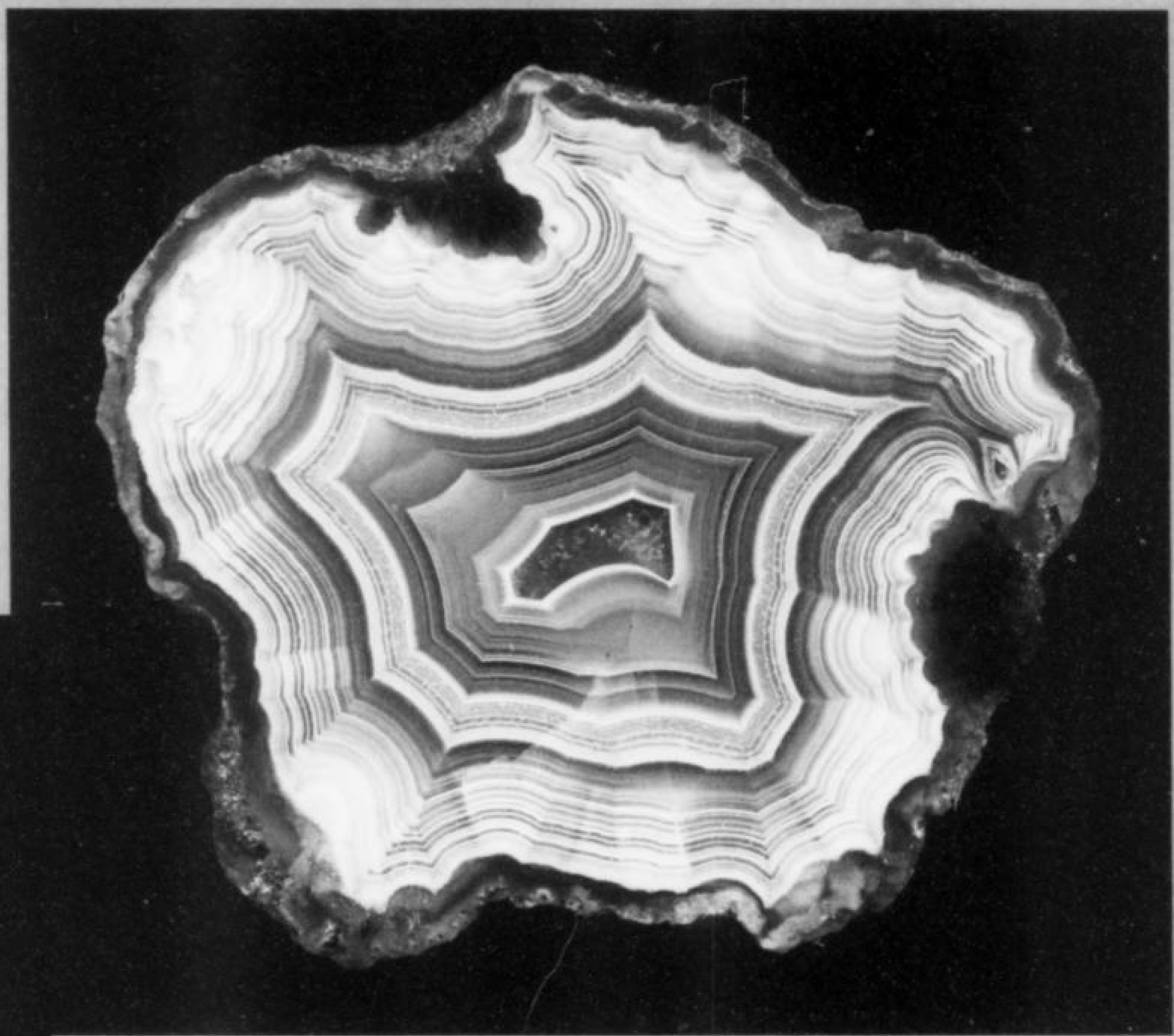


Figure 31. **Laguna agate, 7.1 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**



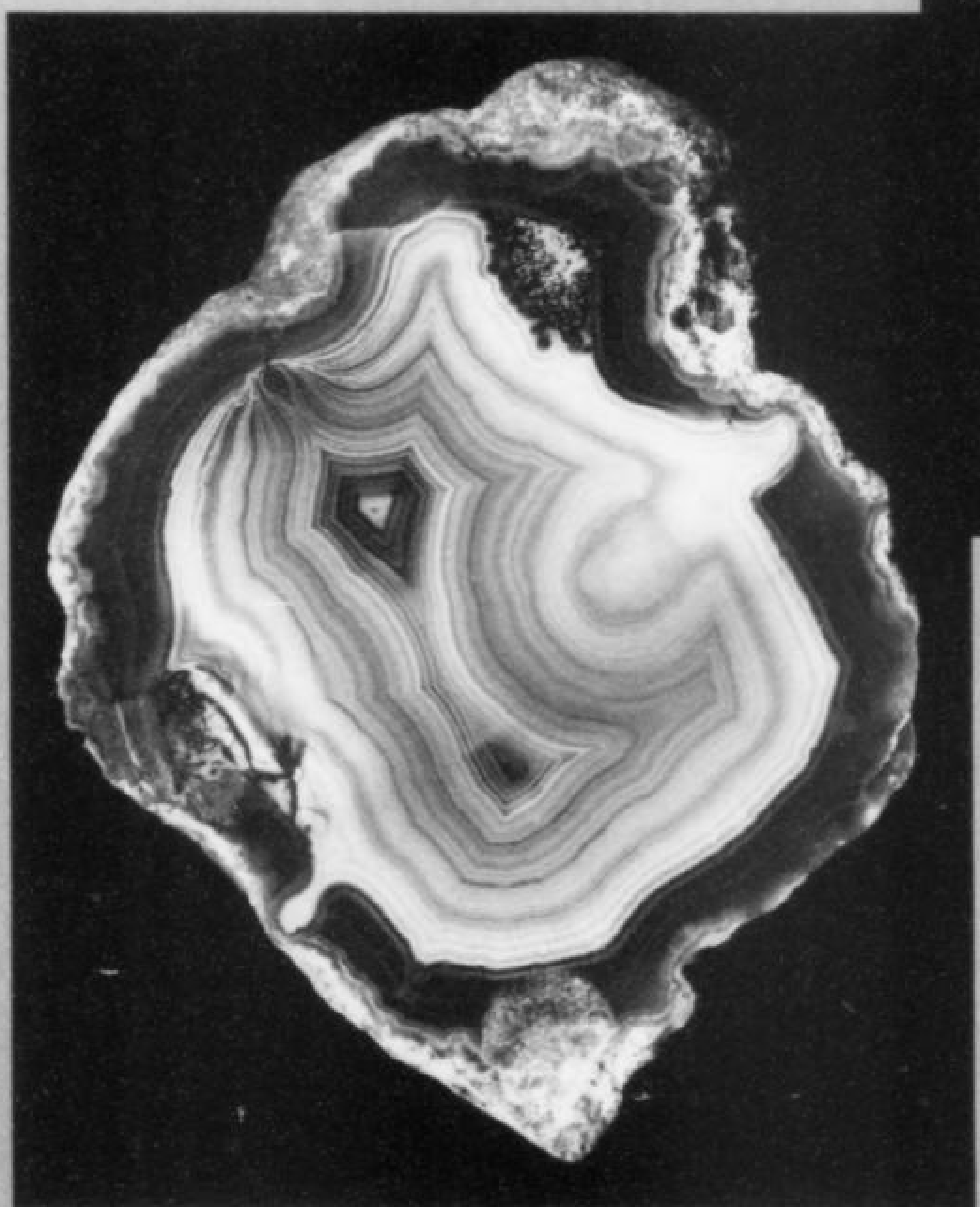


Figure 32. **Laguna agate, 5.3 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**

Figure 33. **Laguna agate, 6.6 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**

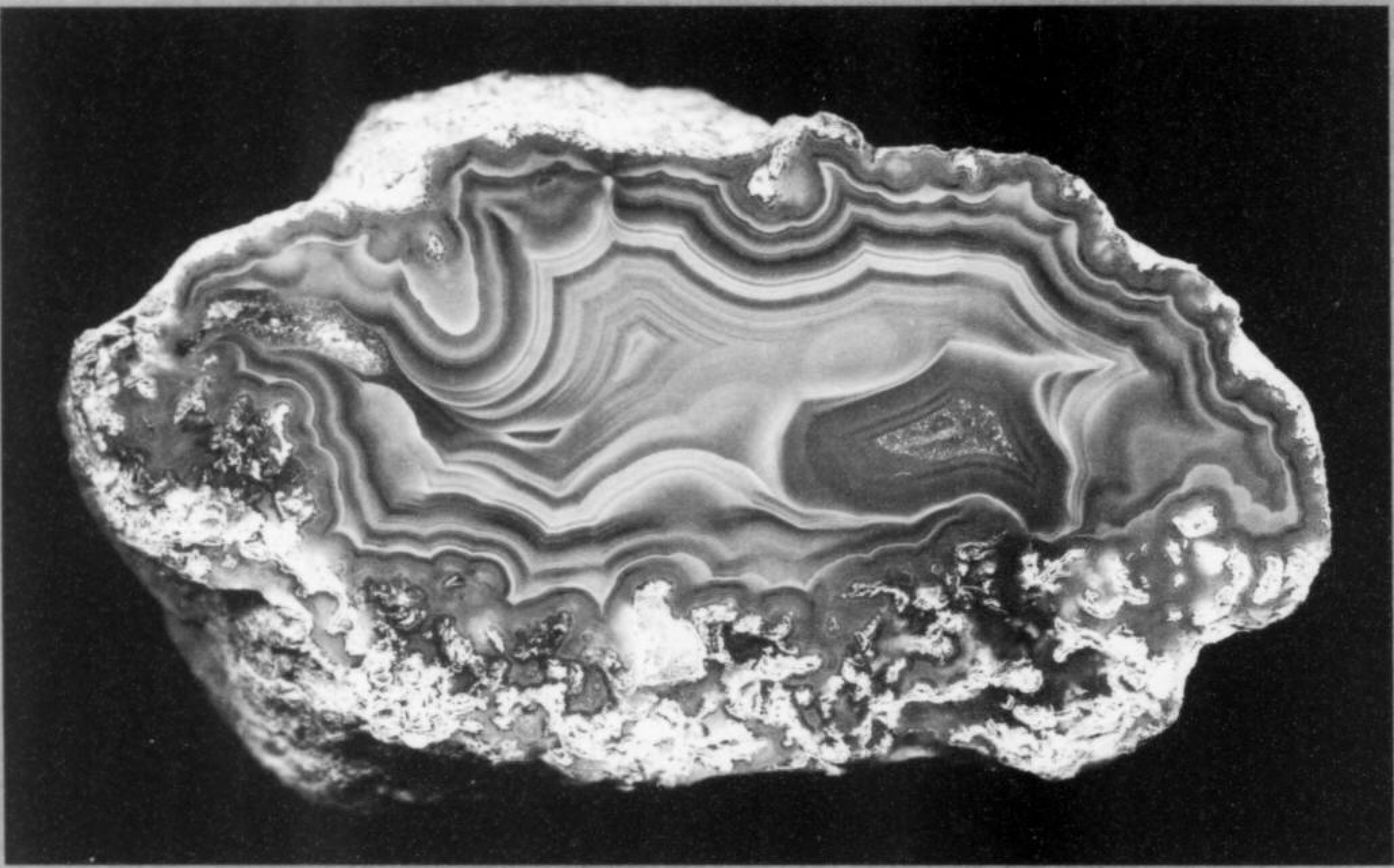


Figure 34. Laguna agate, 8.8 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.

Figure 36. Laguna agate, 9.3 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.

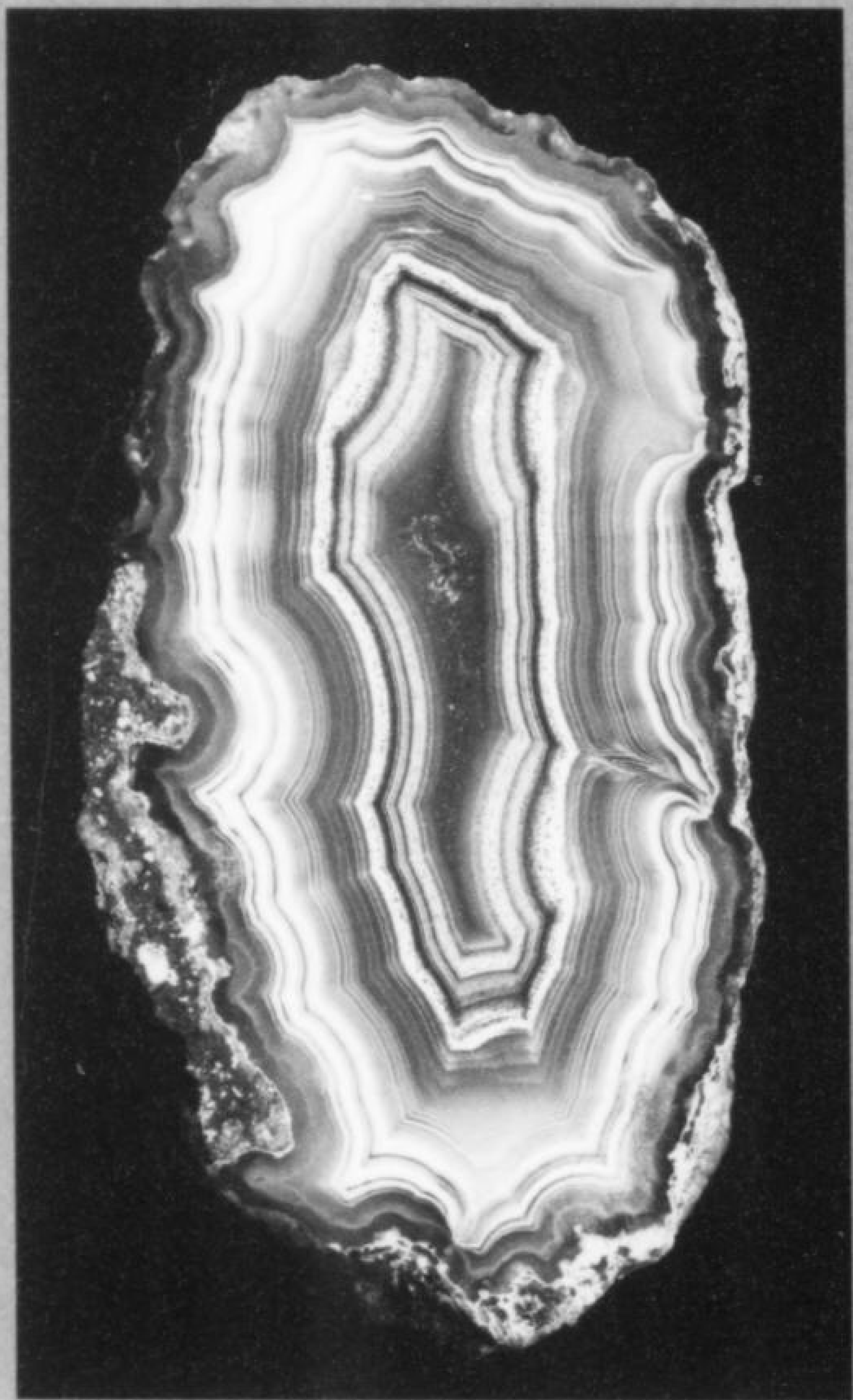
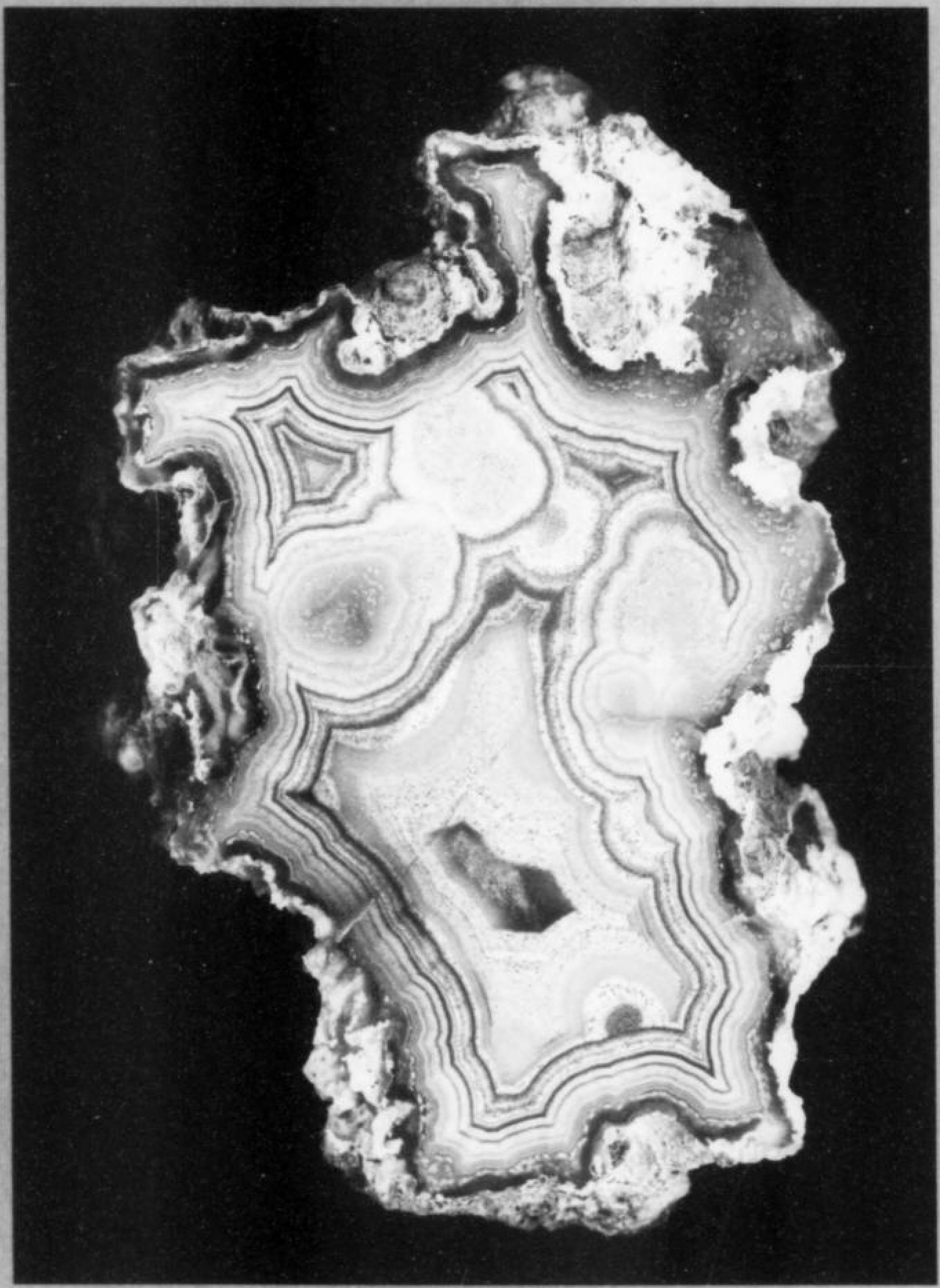


Figure 35. Laguna agate, 7.8 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.



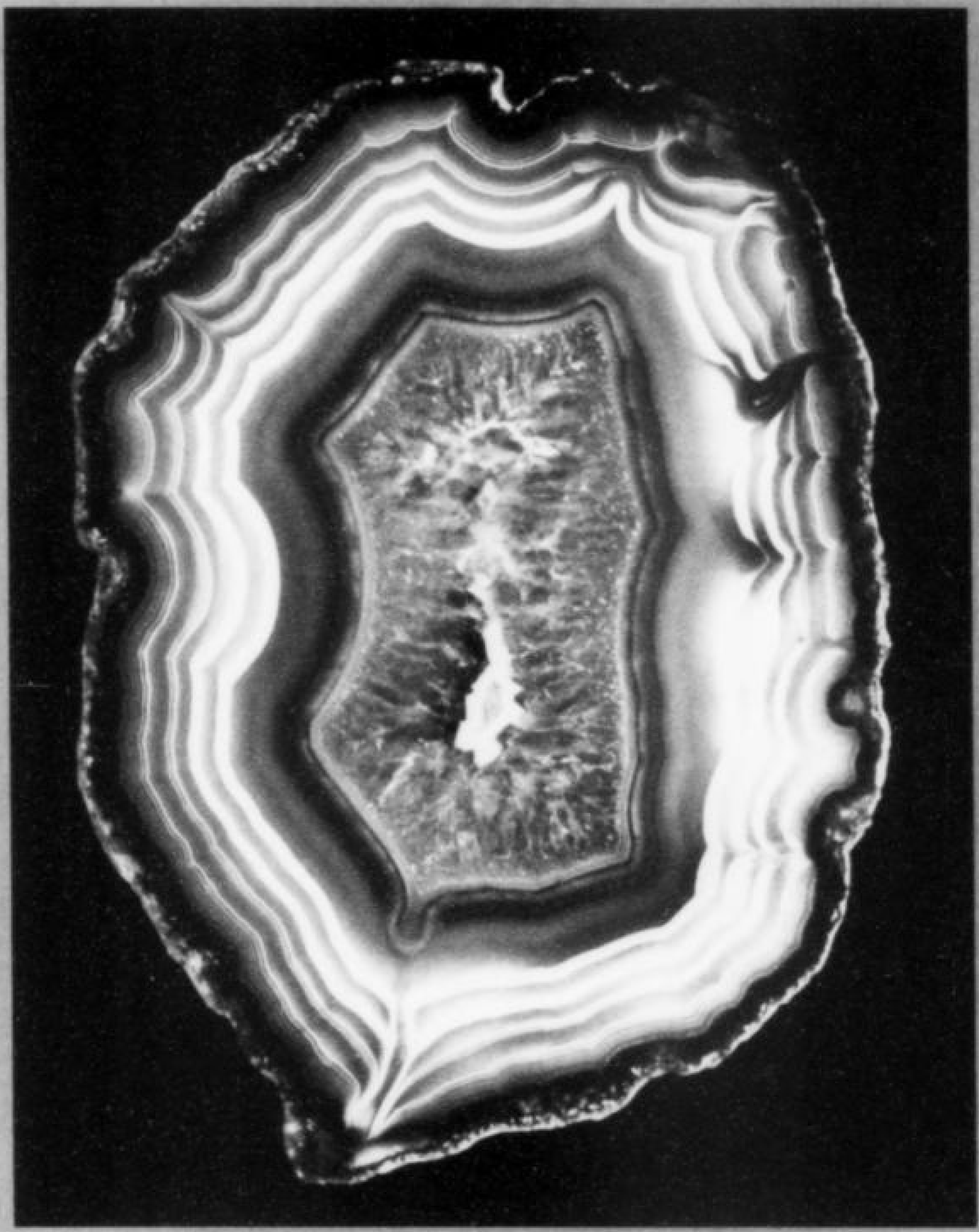


Figure 37. **Laguna agate, 11.2 cm, from east of Estación Ojo Laguna, Chihuahua. David Wilber collection; Jeff Scovil photo.**

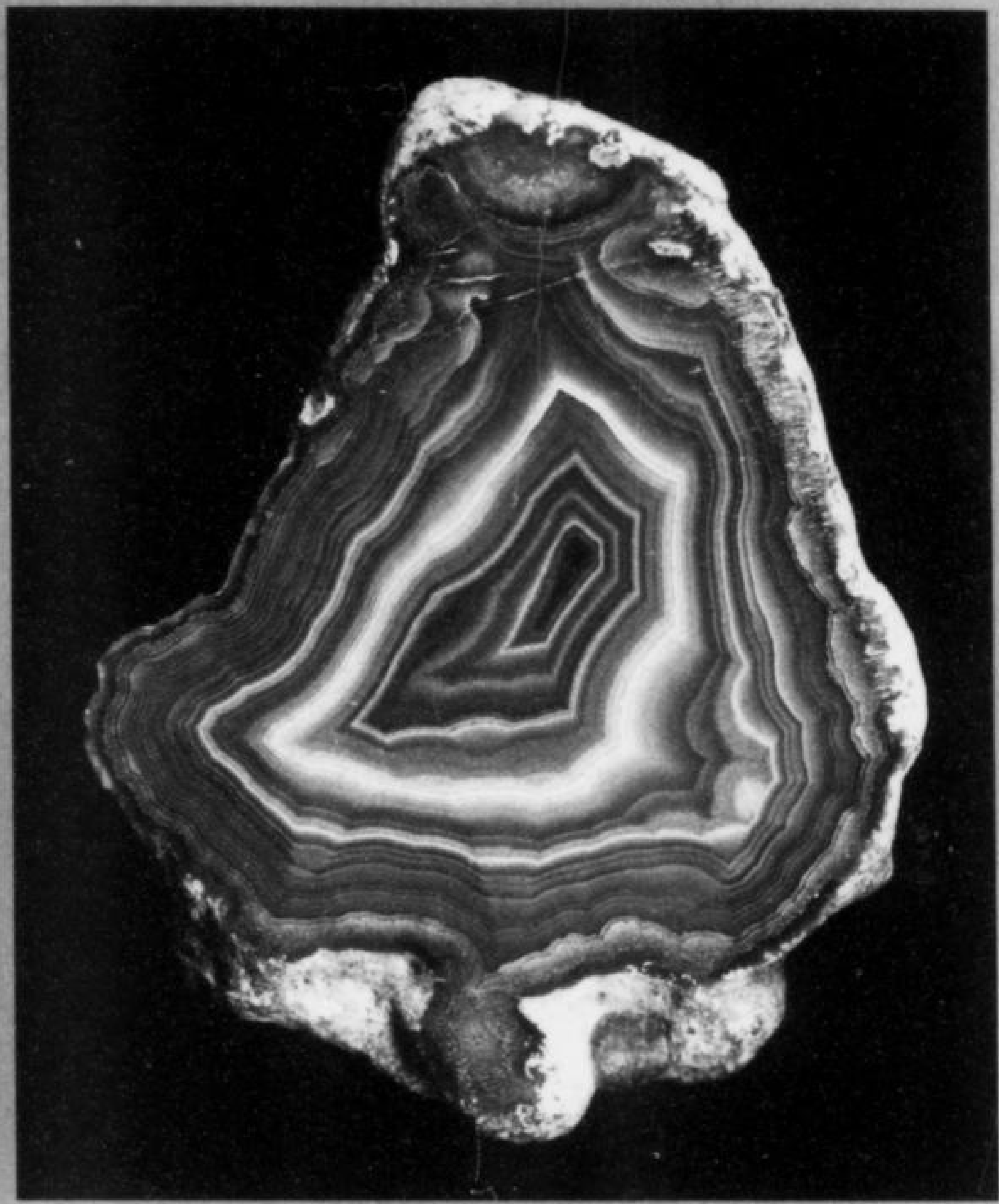


Figure 38. **Laguna agate, 7.4 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**

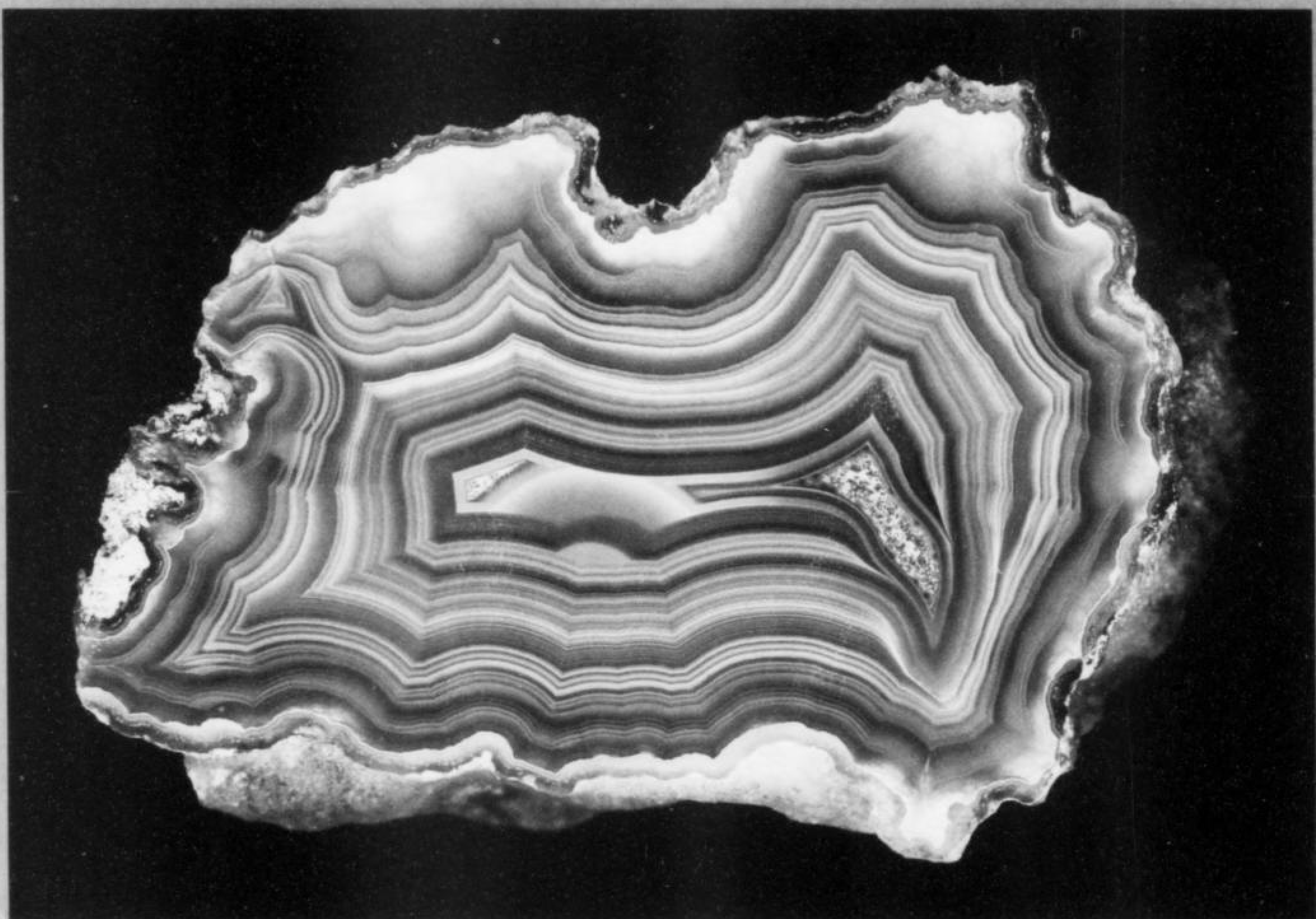


Figure 39. **Laguna agate, 7.7 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.**

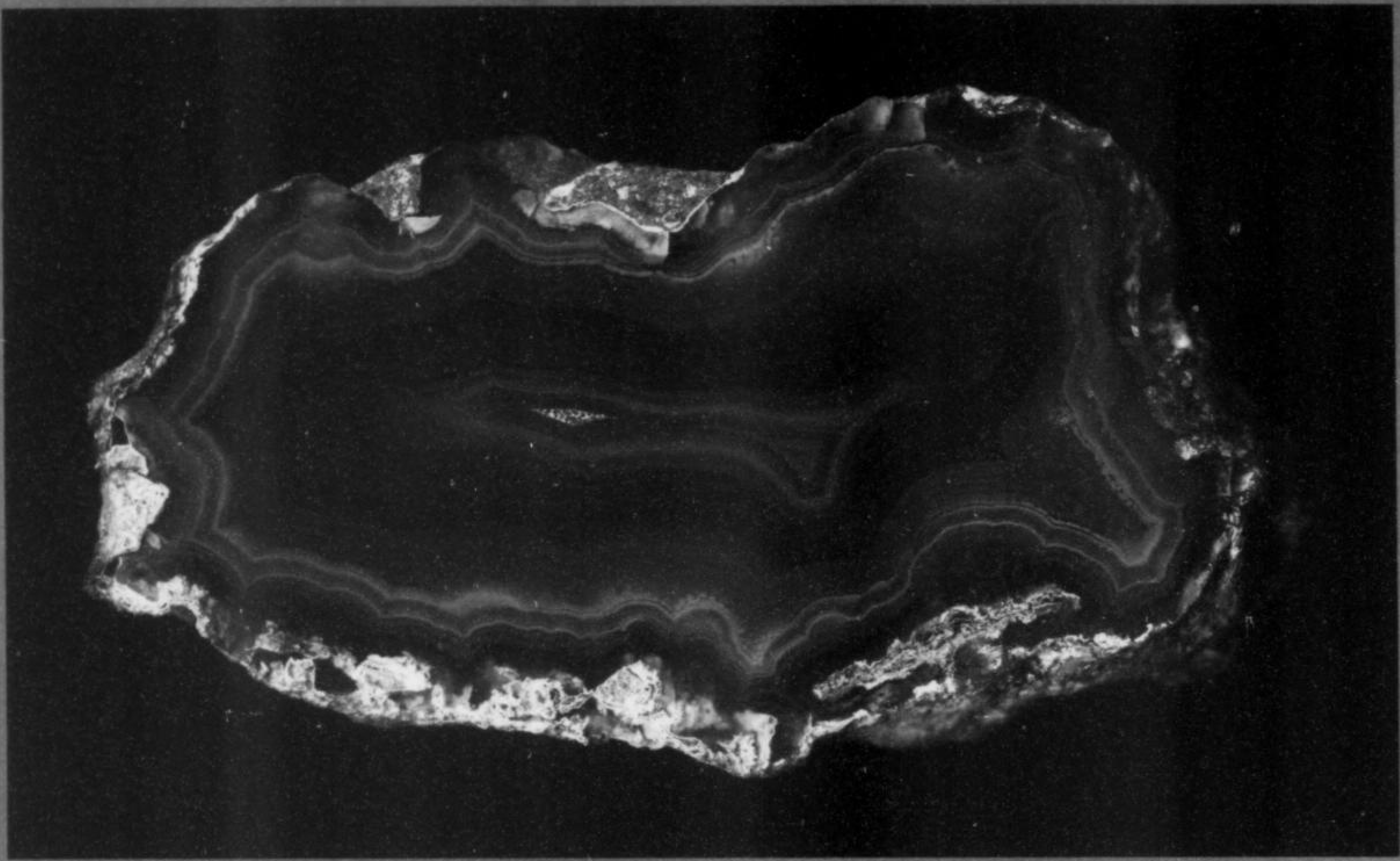


Figure 40. Laguna agate, 8.7 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.

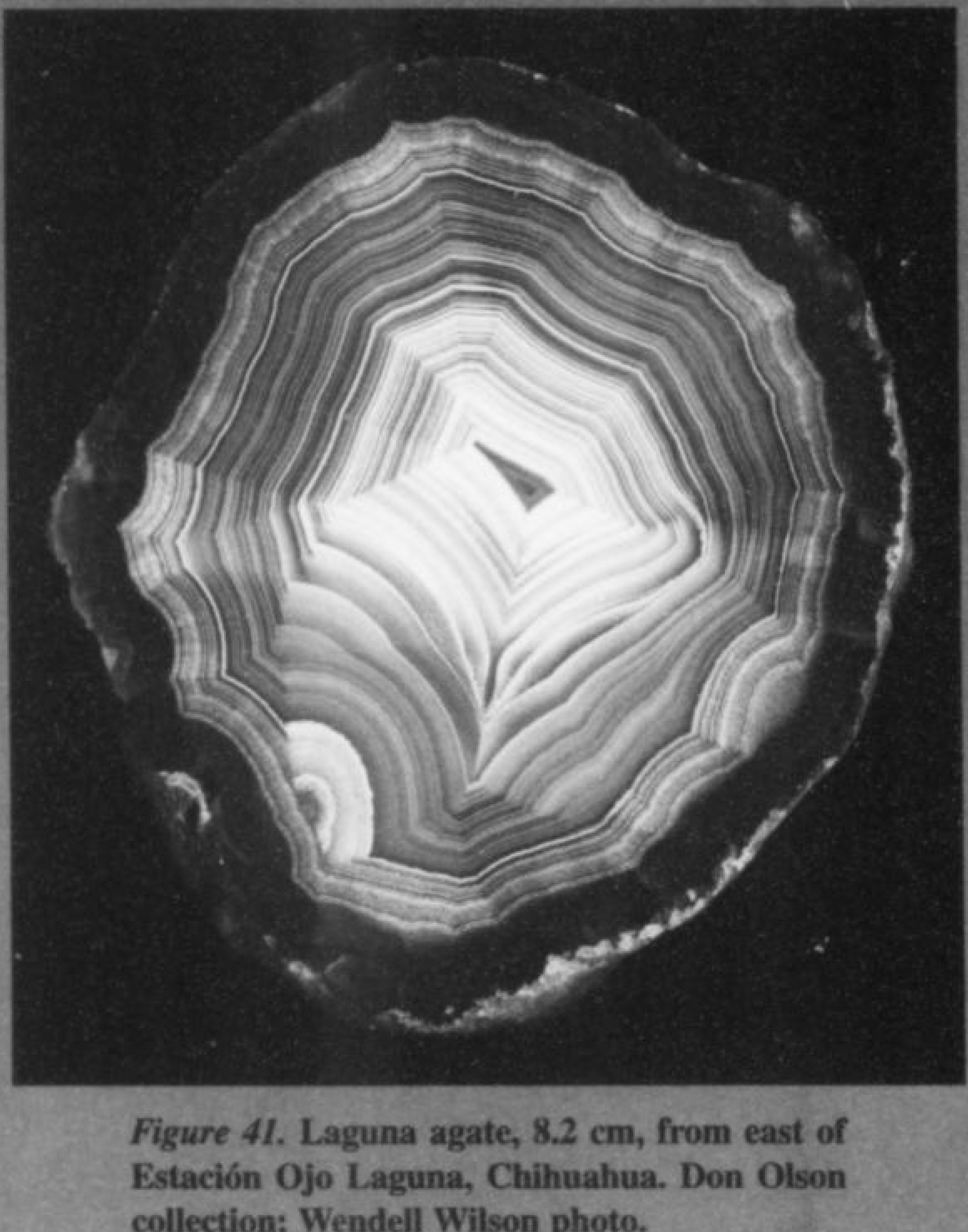


Figure 41. Laguna agate, 8.2 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.

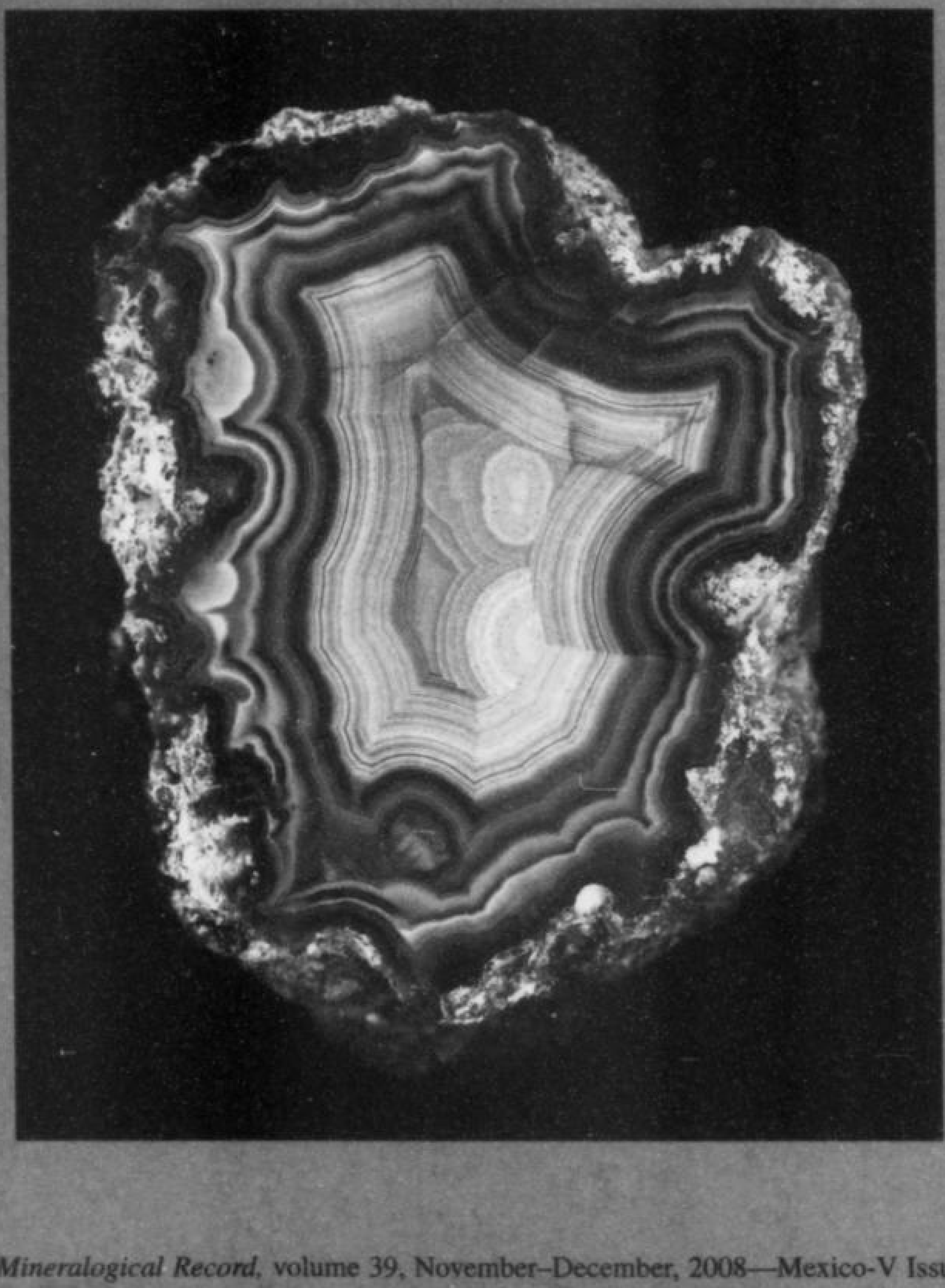


Figure 42. Laguna agate, 6.6 cm, from east of Estación Ojo Laguna, Chihuahua. Don Olson collection; Wendell Wilson photo.

Figure 43. **Crazy Lace Agate, 10.2 cm, from the Sierra Santa Lucia, Chihuahua. Brad Cross specimen and photo.**

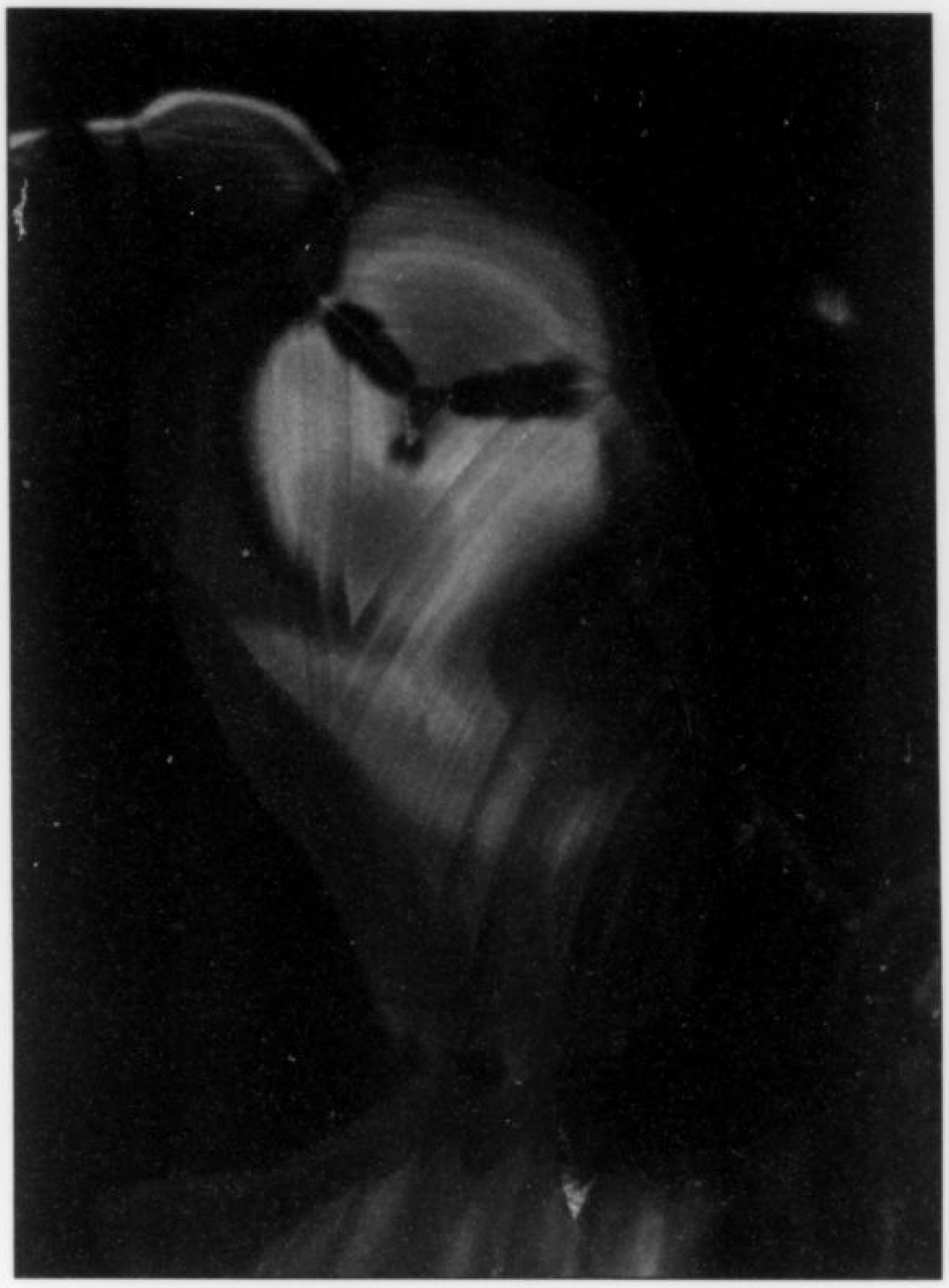


Figure 44. **Apache agate known as "the Hooded Owl," for obvious reasons (5 cm as shown), from Rancho la Viñata, Chihuahua. Brad Cross collection; Jeff Scovil photo.**

and Jesús Gamon. The deposit has not been actively worked since the early 1970s.

Moctezuma Agate

Moctezuma agate is a nodular banded agate with bands in pastel shades of pink, yellow, salmon and tan, as well as white. The banding varies from fine to somewhat heavier. The agate is easily distinguished by its siliceous white "banana peel" exterior, caused by extensive weathering. The vast majority of these nodules range from 1 to 3 inches in size.

"Chromatography," a color-change feature commonly seen in Moctezuma agates, is caused by the separation of coloring agents by semi-permeable layers of chalcedony.

Moctezuma agate is found approximately 15 miles east of Estación Moctezuma, Chihuahua, as float material in the desert flats of Ranchos San Martin and Barreal. At the *Laguna Verde* ("Green Lagoon") claim, Moctezuma nodules can reach more than 12 inches in diameter. However, most of these large nodules are composed entirely of crystalline quartz with only a thin outer rim of vivid salmon-pink and yellow bands.

Parcelas Agate

Parcelas agate is found in the Cerro El Oregano area, 8 miles northeast of Le Barón, Chihuahua. Parcelas agate has many times been mistaken for and marketed as Casas Grandes agate; however, the respective nodules are easily distinguishable both externally and internally. Parcelas agate rinds are fairly rough in texture and are gray, red and green. Their interiors show lavender as well as pale to dark gray banding. The vast majority of the nodules have alternating pale and dark gray bands. The individual bands are usually quite wide compared to other Mexican banded agates. Many nodules were once hollow and have since been filled with manganese minerals (primarily psilomelane and cryptomelane), the probable coloring agents for the agate.

Parcelas agate was initially discovered by Francisco Lucero (from Carmen, Chihuahua) in the late 1950s. The deposit was later mined by Benny Fenn under the concession *Las Parcelas* ("The Parcels").

Sueco Agate

Rancho El Sueco, located in the northwest quadrant of the Sierra del Gallego, produces agate nodules in a wide range of colors, although red, purple, olive, and yellow shades predominate. Identified by their rusty yellow and pitted exteriors, the nodules typically range from 1 inch in diameter up to 5 or 6 inches. It is estimated that more than 80% of all the agates recovered from Sueco are hollow.

Jesus Gamon is credited with the early mining of the majority of the Sueco agates. In recent years, the deposit has been mined by Ramon Olivas (from Ciudad Juárez).

CONCLUSION

For over a century Mexico has produced some of the finest and most colorful agates to be found anywhere. The history of many of these agate localities is as colorful as the specimens themselves. With over 100 different varieties of Mexican agate currently recognized (and the list is still growing), it would be beyond the scope of this article to address them all and describe the particular characteristics of each type, but the ones discussed here are among the major varieties; thus the list can serve as an introduction to the colorful specialty of Mexican agate collecting. Mexican agates have and will continue to be ranked among the finest agates produced anywhere.

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e-mail: icminerals@earthlink.net

ItalianMinerals.com
Quality Minerals from Italy & Worldwide
www.ItalianMinerals.com
e-mail: italianminerals@libero.it

Jewel Tunnel Imports
Indian & Worldwide Minerals Wholesale
www.jeweltunnel.com
e-mail: jeweltunnel@hotmail.com

Key's Mineral Collection
Kiyoshi Kiikuni
www.keysminerals.com
e-mail: keysminerals@keysminerals.com

Lawrence H. Conklin
Over 50 years selling fine minerals
www.LHConklin.com
e-mail: LHC@LHConklin.com

Marcus Grossmann Minerals
Top specimens worldwide
www.THE-MINERAL-WEB.com
e-mail: info@THE-MINERAL-WEB.com

The Mineral and Gemstone Kingdom
Reference guide to minerals & gemstones
www.minerals.net
e-mail: hershel@minerals.net

The Mineral Cabinet
Select Mineral Specimens, Min Records
www.mineralcabinet.com
e-mail: themineralcabinet@comcast.net

Mineralium.com
Fine Mineral Specimens Worldwide
www.mineralium.com
e-mail: info@mineralium.com

Mineralogy Database
On-line User-Frndly, Up-to-date Mineral Data
http://webmineral.com

Minerals Unlimited
Rare Species to Common Minerals
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e-mail: wendi@mineralsunlimited.com

Minernet.it
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e-mail: info@minernet.it

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Stuart's Minerals
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The Sunnywood Collection
Bill and Elsie Stone
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