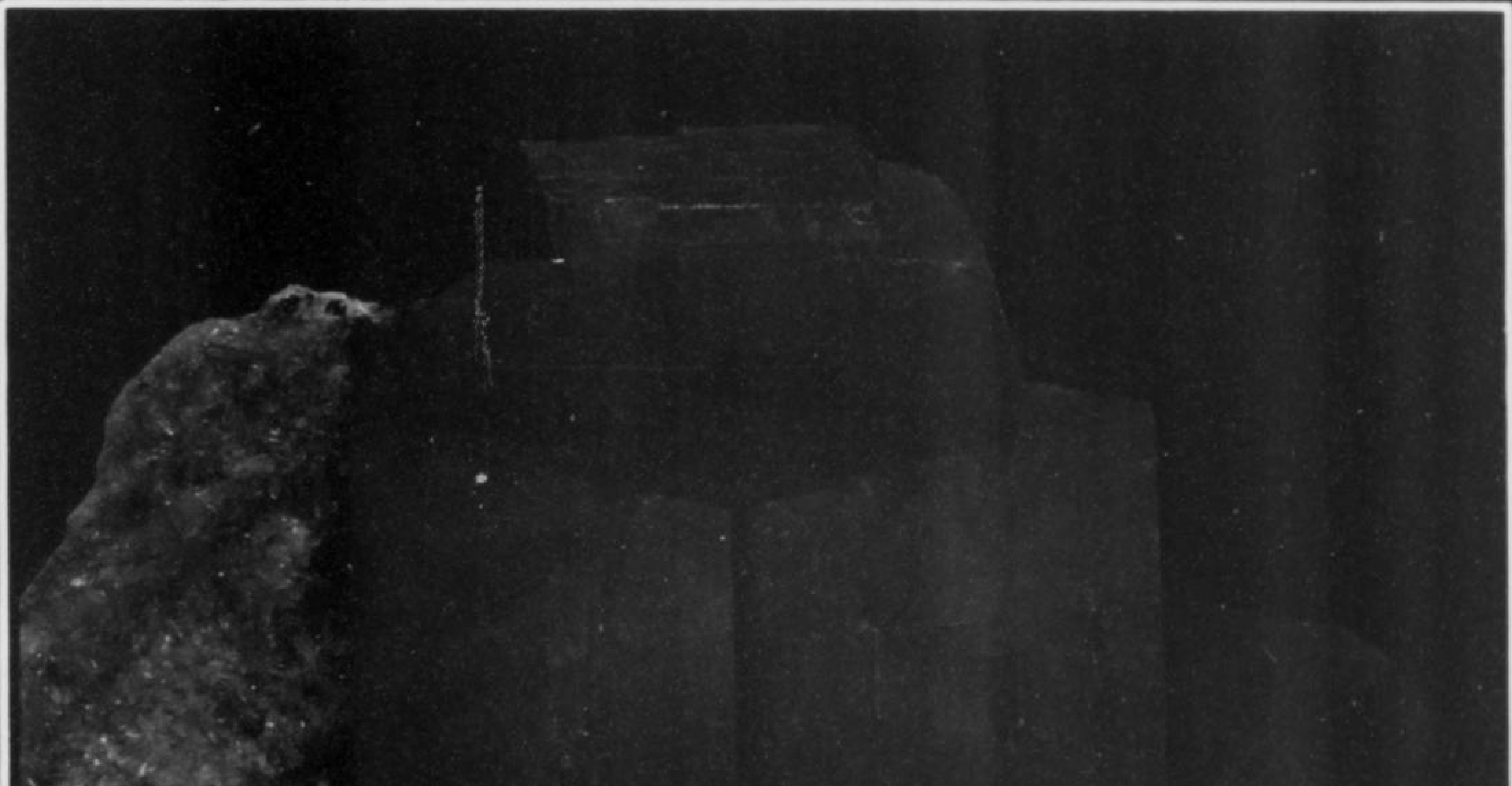
the Sweet Home Mine



Mineralogical Record

July-August 1998 • Volume 29 Number 4 • $20

KRISTALLE

Wayne & Dona Leicht, 875 North Pacific Coast Highway, Laguna Beach, CA 92651
(714) 494-7695 . . . 494-5155 . . . FAX (714) 494-0402
Open Tues.-Sat. 10-5. (Closed Sun.-Mon.)

photo by Harold and Erica Van Pelt, Los Angeles

NOTE: Please call ahead for our travel schedule–we would hate to miss your visit!
WEB: http://www.kristalle.com
E-mail: leicht@kristalle.com

The Sweet Home Mine

Park County, Colorado

This publication
is dedicated to
F. Leonard Beach,
whose undying faith in
the Sweet Home Mine
made it all happen.

THE SWEET HOME MINE

PARK COUNTY, COLORADO

by
Thomas Moore
Bryan K. Lees
Karen J. Wenrich
Steve Voynick
Jack A. Murphy
James F. Hurlbut
T. James Reynolds
Regina Aumente-Modreski
Dean Misantoni
Miles L. Silberman

The Mineralogical Record

Tucson
1998

The Mineralogical Record

◆

July–August 1998 volume 29, number 4

Editor and Publisher: Wendell E. Wilson

The Mineralogical Record (ISSN 0026-4628) is a bi-monthly publication of the Mineralogical Record, Inc., a non-profit organization. Special second-class postage (USPS 887-700) paid at Tucson, Arizona, and additional mailing offices.
POSTMASTER: Send address changes to: The Mineralogical Record, P.O. Box 35565, Tucson AZ 85740.

Design and layout by Wendell E. Wilson
Typesetting by Capitol Communications, Crofton, Maryland
Color separations by Hollis Phototechnics, Tucson
Printed in Easton, Maryland, by Cadmus Journal Services

Single copies of this issue are available, while the supply lasts, at $20 per copy (softcover) plus $1 postage and handling, and $49 per copy (hardcover) plus $2 shipping ($4 foreign).

Subscription rates for one year:
Individuals (U.S.) $47
Individuals (foreign) $51
Libraries, companies & institutions (worldwide) $120
First class and airmail rates available on request

The Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740
Tel: 520-297-6709
FAX: 520-544-0815

Editorial & Advertising Office
4631 Paseo Tubutama
Tucson, AZ 85750
Tel: 520-299-5274
FAX: 520-299-5702

FRONT COVER: The "Snow Cone" rhodochrosite specimen, 17 cm, found in the Good Luck Pocket, Sweet Home mine, in 1992. Sweet Home Rhodo, Inc. specimen; photo by Harold and Erica Van Pelt.

Foreword

Every mineral collector can probably list a large number of great mineral discoveries that have been made throughout the history of collecting. Some of these finds yielded thousands of specimens now in countless museum and private collections worldwide. And yet, in the majority of cases, little or nothing has been recorded about the exact circumstances of the discovery: the people involved, the precise locations of individual specimens, the timetable of finds, the difficulties overcome, the strokes of luck (good and bad) . . . in short, the *story* is missing. The blood and sweat and headaches, the thrill of victory and the agony of defeat, are historical chapters lost forever.

By great good fortune, some information has been saved. This special issue of the *Mineralogical Record* documents what may well be the greatest adventure in specimen collecting in our time: the Sweet Home mine operation. Many thousands of specimens have reached the market as a result of the project, and thousands of collectors and museums now proudly display stunning examples of cherry-red rhodochrosite and other species from the Sweet Home mine. The experience of owning those specimens can now be enriched by knowing the full story of how they came to be and how they were recovered. Take it from an editor who has spent decades trying to root out such data for important occurrences: this is a rare treasure.

The Sweet Home operation has been unique in many ways. Most similar specimen-mining endeavors are unprofitable and short-lived, whereas this one has made a fortune and has persisted for the better part of a decade. While other operations have relied on the limited technical background of one or two individuals, the Sweet Home operation has from the start been professionally organized and financed, and has brought to bear the training and experience of a number of professional geologists, geophysicists, geochemists, mineralogists and mining engineers, not to mention seasoned miners who ultimately became very well-schooled in the special techniques of specimen mining. Through the synthesis of all these skills, and under the inspired guidance of Bryan Lees as the project's head, new technologies were applied and new techniques developed that have resulted in what is surely the most professional and technically advanced specimen recovery and preparation operation in history.

I will resist the temptation here to rave on about the unique beauty, quality and fascination of the Sweet Home specimens. The reader will already know this and, if not, will achieve this realization after a brief flip through this issue.

As an editor, I don't always get everything I want in an article or an issue. But in this case, it's all here: Practically a day-by-day account of the best discoveries, an in-depth review of the early history of the locality, a thorough review of the geology, details on all the species found, and a fascinating collection of technical data on everything from origins to exploration methods. And all of this is augmented by abundant illustrations showing everything from underground mining to many of the best specimens removed. It is a collector's feast that warms an editor's heart.

Clearly this is one of those special issues that deserves a hardcover edition; everyone owning a valuable Sweet Home piece will surely want to keep a special copy along with his specimen. So we have gone ahead and ordered a run of 500 copies with sewn bindings and gold-stamped, bonded-leather covers, which will be available at our usual price of $49 plus $2 shipping ($4 shipping outside of the U.S.). Copies can be ordered by phone or fax from the Circulation Manager. Bear in mind that handbinding takes time, but order now to assure that you get one, and we will ship them out as soon as we receive them from the binder.

On behalf of the readers and staff of the Mineralogical Record, I would like to thank the authors, reviewers and photographers involved for their excellent and timely work, especially Bryan Lees who spearheaded the writing and photography like an experienced old editorial wrangler. Karen Wenrich, Peter Modreski, Bryan Lees, Bill Silberman, Paul Hlava, Bill and Carol Smith, Bob Jones, Bill Tanaka and Steven Morehead all assisted in the review process. I would also like to thank those generous individuals who donated the funds that were absolutely essential to the publication of this project: Jim and Chris Duncan, Bryan and Kathryn Lees, John and Pit Lucking, Eugene and Rosalind Meieran, Randolph S. Rothschild, Philip Rust, the Sweet Home Rhodo corporation, and Martin Zinn III. I hope that all of these people will be justly proud of the result.

Wendell E. Wilson

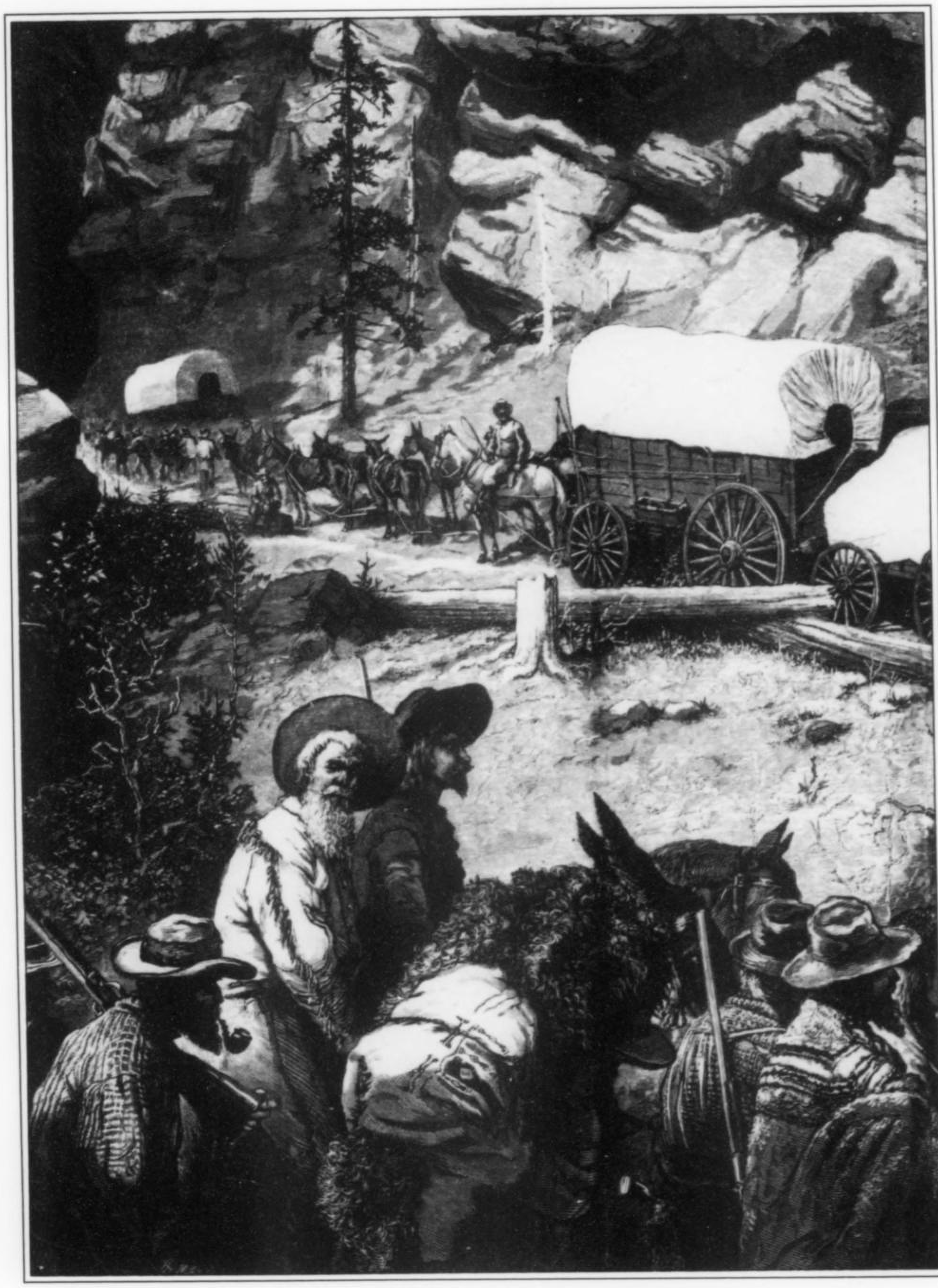


Figure 1. **Prospectors traveling to the Colorado gold fields, 1859. Some of them found gold in the head-water creeks of the South Platte River, opening the Alma district in 1861. Engraving by Paul Frenzeny and Jules Tavernier, published in *Harper's Weekly*, May 1, 1875.**

CONTENTS

Figure 2. **Horse-drawn freighter moving supplies and ore for the Sweet Home mining operation, circa 1922. Photographer unknown.**

PREFACE

Mineral collecting is often compared to treasure hunting. Whether you are rummaging through the halls of the Executive Inn during the Tucson Show looking for that elusive bargain or tunneling underneath a mountain searching for a fabulous crystal pocket, the thrill is the same; and you just can't wait for the next discovery.

Much of the excitement surrounding the Sweet Home mining project, for participants and onlookers alike, was in the thrill of seeing new crystal pockets. Everyone wanted to see what nature would reveal next. Each time a new pocket discovery was made, people were astounded by the variety and quality that could be produced from such a small mine as the Sweet Home.

This series of articles on the Sweet Home adventure was put together to share the spirit of discovery with everyone. Some of the articles take you through a day-to-day account of life at the Sweet Home mine, highlighting major discoveries while pointing out the severe difficulty of mining for mineral specimens.

Other articles highlight the scientific work done to broaden our understanding of how rhodochrosite crystals grow and where we might find them. During the first few years of the project, many questions were raised: Why are the rhodochrosites from the Sweet Home mine so red? Why do they occur in some areas and not in others? Why are some rhodochrosites better than others? To answer these questions, a three-year scientific research program was undertaken. The answers had a profound influence on exploration and development programs at the Sweet Home mine.

The research culminated in a series of discoveries. First, the results were applied to problems at the Sweet Home mine. As more and more information was accumulated, we realized that we were breaking new ground in the study of crystal chemistry and its application to mineral specimen mining; so, it was decided to share the findings through a series of published articles. As additional time went by, someone had the notion to combine the articles and stories into a single publication about the whole Sweet Home experience.

So here you have it, the Sweet Home Experience. We hope you enjoy it as much as we have.

ACKNOWLEDGMENTS

After the first year of the Sweet Home mine project, someone came up to me and asked how Kathryn and I managed to collect so much material on our weekends off from our day jobs. The first time I heard this I broke up laughing and proceeded to set the story straight. No fewer than 100 people were directly involved at various times to bring off the successes at the Sweet Home mine.

I would like to thank every person and organization who devoted special effort to the Sweet Home project: Mark Akerley, Air Rentals Company, American Mine Services, David Bassinger, Leonard and Marion Beach, Dennis Beals, Scott Betz, Bill Blandchard, Dave Bunk, *Compressed Air* magazine, Bill Coors, The Coors Foundation, Paul Cory, The Denver Museum of Natural History, The Division of Minerals and Geology, Jim Duncan, Greg Francis, The Friends of Mineralogy, Sandor Fuss, *Gems and Gemology* magazine, The Greater Denver Area Gem and Mineral Council, Bill Hawes, Pat Haynes, David Helt, Russ Honea, Marie Huizing, Jim Hurlbut, Bob Jones, Bill Kazel, Gene Kooper, Bernie Kowalski, *Lapis* magazine, Robert Lorda, John and Pit Lucking, Rory and Carrie MacDonald, Peter Megaw, Gene and Rosalind Meieran, *Mineralien Welt* magazine, The Mineral News, *The Mineralogical Record*, Dean Misantoni, Regina Modreski, Tom Moore, Jack Murphy, Denise Patton, Jim Reynolds, Richard and Helen Rice, Roy Rizzardi, George Robertson, *Rock and Gem* magazine, *Rocks and Minerals* magazine, Mike Savage, Jeff Scovil, Tony Sherrill, Bill Silberman, Bill and Carol Smith, Jim Smith, John and Dorothy Soules, Dan Stevens, Bill Stone, Graham Sutton, Bill Tanaka, Jack Thompson, The Town of Alma, The Town of Fairplay, The Tucson Gem and Mineral Society, Chuck Turley, The US Forest Service, Harold and Erica Van Pelt, Steve Voynick, Stewart Wallace, Mike Warren, Karen Wenrich, Geoffrey Wheeler, David Wilber, Wendell Wilson, Tom Young and Marty Zinn.

My special thanks go out to everyone who supported our effort through specimen purchases and referrals to our company. Without this support, everything would have folded up long ago.

And finally, I wish to thank Kathryn, my wife, who was always there to help pick up the pieces and keep the business and home running while I was away "playing" underground.

Bryan K. Lees
President
Sweet Home Rhodo, Inc.

Figure 3. **Sweet Home mine crew showing ore samples at portal, Joe Kasel on the left; ca. 1922. Photographer unknown.**

HISTORY

The Sweet Home Mine, 1873–1989

Steve Voynick
P.O. Box 1285
Leadville, Colorado 80461

As silver mines go, the Sweet Home mine was a failure. It was a hole in the ground that devoured hopes and money, and gave very little in return. Based solely on its unimpressive silver output, the Sweet Home should have faded into obscurity and abandonment a century ago, joining many others that became nothing more than collapsed portals and flooded workings. However, if the Sweet Home didn't have much silver, it did indeed have a stubborn ability to survive.

Survival, of course, has led to no small measure of fame. Today, the Sweet Home mine is among the world's better-known mines, at least in the eyes of mineral collectors, for whom the name has become synonymous with fine rhodochrosite.

The Sweet Home mine is located in the Alma mining district on the eastern slope of central Colorado's Mosquito Range. The district, near the headwaters of the South Platte River, is about 80 road miles west of Denver. Alma, one of North America's highest mining districts, includes several 14,000-foot peaks; most of its mines are at or well above the 11,300-foot timberline. The Sweet Home mine is actually one of the district's lower mines, located near the timberline in Buckskin Gulch on the southern slope of Mount Bross, 4.5 miles west of Alma.

The Alma district opened in 1861 when prospectors, in one of the last major strikes of the Pikes Peak gold rush, found placer gold in the South Platte River headwater creeks. Many miners turned quickly to lode mining when they learned that numerous thin, gold-bearing quartz veins laced the bedrock of Buckskin Gulch. Miners crudely crushed the quartz ore, washing it in stream-bed arrastras. Both the placer deposits and the quartz veins, while rich, exhausted quickly. By 1864, the Alma mining district was largely deserted.

Mining began anew in 1871 when prospectors discovered outcrops of silver mineralization just below the summit of 14,172-foot-high Mount Bross and developed the Moose mine. Other silver discoveries soon followed, and the town of Alma became the district trading center in 1873.

That same year, prospectors discovered the mineralized outcrops that would become the Sweet Home mine. The outcrops were located 1,200 feet above Buckskin Creek and just above a boulder field that formed the lower talus slope of Mount Bross. The initial claims, the Sweet Home and Pulaski lodes, measured 50 by 3,000 feet. Both were patented on November 28, 1876, receiving patent numbers 106 and 107, among the earliest patents granted under the General Mining law of 1872.

Miners initially confined their development work to the discovery veins, along which they drove several short tunnels. The Sweet Home mine veins were quite rich, but also narrow and erratic. Early development and production records apparently no longer exist, but the Sweet Home mine was at best a marginal silver producer.

Although the early Sweet Home miners failed to find a silver bonanza, they did note an unusual presence of rhodochrosite as a gangue mineral. The rhodochrosite was found not only in common massive form, but also as well-developed, deeply colored, euhedral crystals. The crystals were attractive enough to draw attention, for a federal mineralogical report for 1876 notes: "Rhodochrosite, Sweet Home mine, Park County, very beautiful specimens" (Endlich, 1878).

Sweet Home mine rhodochrosite specimens apparently were collected and sold from the 1870's to the early 1890's. Museums in both the United States and Europe own rhodochrosite-on-matrix specimens that match the mineralogy of the Sweet Home specimens being mined today. These so-called "pre-1900" specimens are cited only as "Alma" or "Colorado," but certainly originated in the Sweet Home mine (M. Rausch, pers. comm., 1995).

Rugged topography, extreme elevation, poor roads, and long, bitter winters combined to make mining in the Alma district difficult. Miners used burros to pack supplies up to the higher

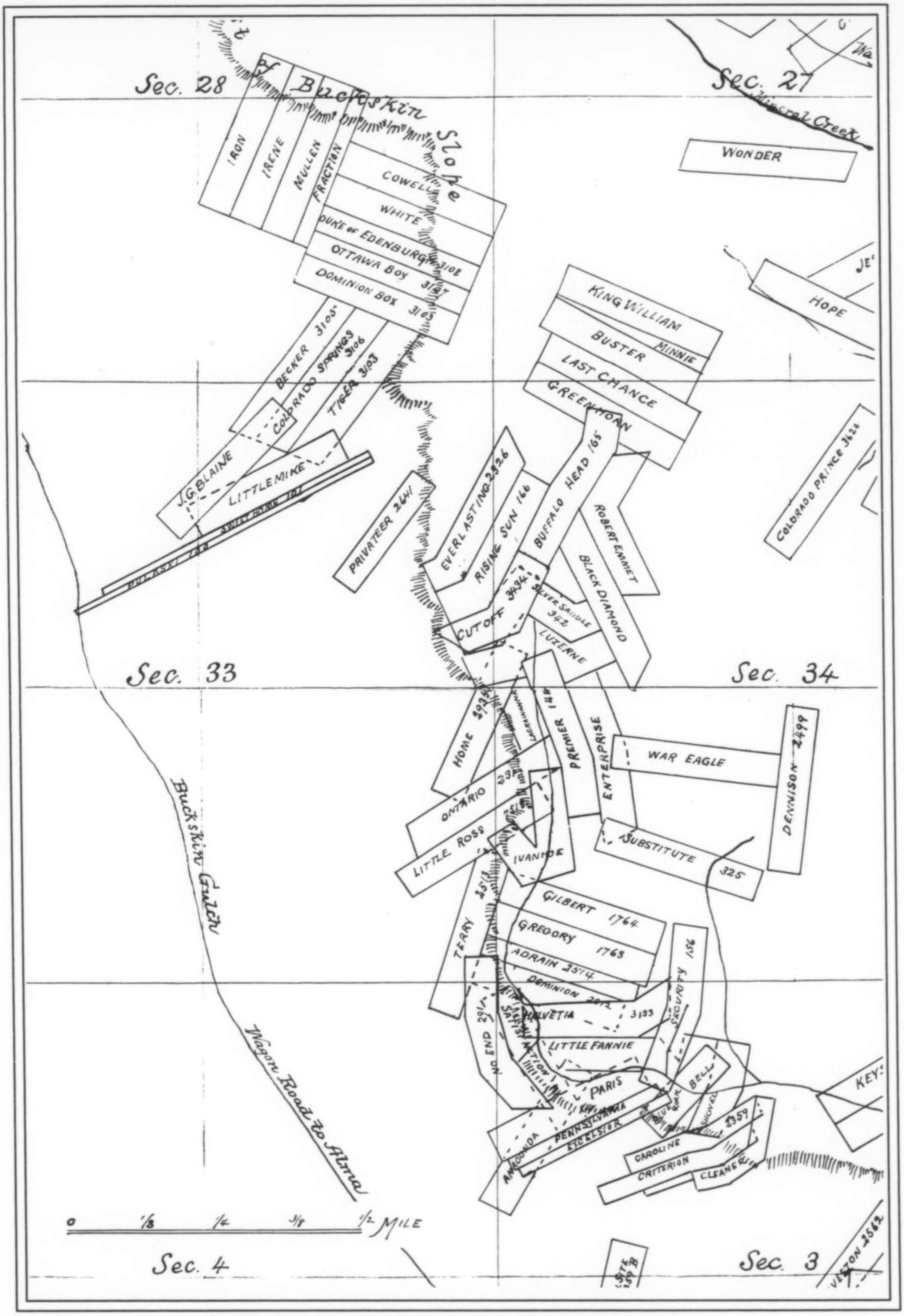


Figure 4. **Mines in the Alma mining district, ca. 1890. The Sweet Home mine is the long, narrow claim at center left in Section 33.**

***Figure 5.* View looking northwest up Buckskin Gulch. Sweet Home mine is located near the center of the photo at the bottom of the gulch. Mount Bross is on the right and Mount Democrat is on the left. Photo by Chauncey Walden.**

mines and bring ore back down to the lower roads. Nevertheless, by 1878 the Moose, Dolly Varden, and Russia mines, high on Mount Bross and Mount Lincoln, had produced more than $3 million in silver.

By the late 1880's, booming western silver production, to which the Alma district had contributed, had created a national silver glut. To prop up falling silver prices, Congress passed the Sherman Silver Purchase Act of 1890, mandating federal purchase of 54 million troy ounces of essentially unneeded silver each year. Federal subsidization supported the price at just about $1.00 per troy ounce. When Congress repealed the Act in 1893, the price plummeted to 60 cents per troy ounce and the silver market collapsed. Most western silver mines, including those of the Alma district, shut down.

By then, after 20 years of operation, the Sweet Home mine had shipped an estimated $185,000 in ores containing silver, lead, copper, and a little gold (Beeler, 1933). After mining, shipping and smelting costs, it is unlikely that the mine ever earned a profit on such ore.

A 1933 Sweet Home mine survey (Beeler, 1933) estimated the extent of the original five tunnels at 1,040 feet. Commenting on the nature of early mining at the Sweet Home and other Alma district mines, Beeler wrote:

> That these ores were sometimes almost unbelievably rich, there can be no doubt, and there is no doubt as to the haphazard manner in which they were mined and the product scattered, often leaving no record except a local legend of what had been found.

In 1912, a Colorado State Geological Survey bulletin (Patton, Hoskin, and Butler, 1912) reported on the Alma district, including the Sweet Home mine, which the writers refer to as both the Sweet Home and the "Home Sweet Home." Ice and caving had prevented a thorough survey of the Sweet Home mine, but assays of four ore samples collected from adit dumps contained between 43 and 193 ounces of silver per ton. Based on examination of dump material, the writers estimated that vein widths ranged from 8 to 24 inches. The report also noted the presence of rhodochrosite ("manganese spar").

The Alma district revived once again in 1915, when rising wartime base metal prices stimulated western metal mining. The Sweet Home mine did not produce during the war, but miners apparently began driving a lower adit, called the Combination tunnel, as early as 1918.

Documentation of mine operations began in 1922, when Edwin C. Spray, a Denver businessman, became a stockholder in the Sweet Home Gold and Silver Mining and Milling Company. Spray would eventually become sole owner of the Sweet Home group of claims.

When the Pittman Act of 1922 restored the price of silver to $1.00 per troy ounce, the Sweet Home mine embarked upon an

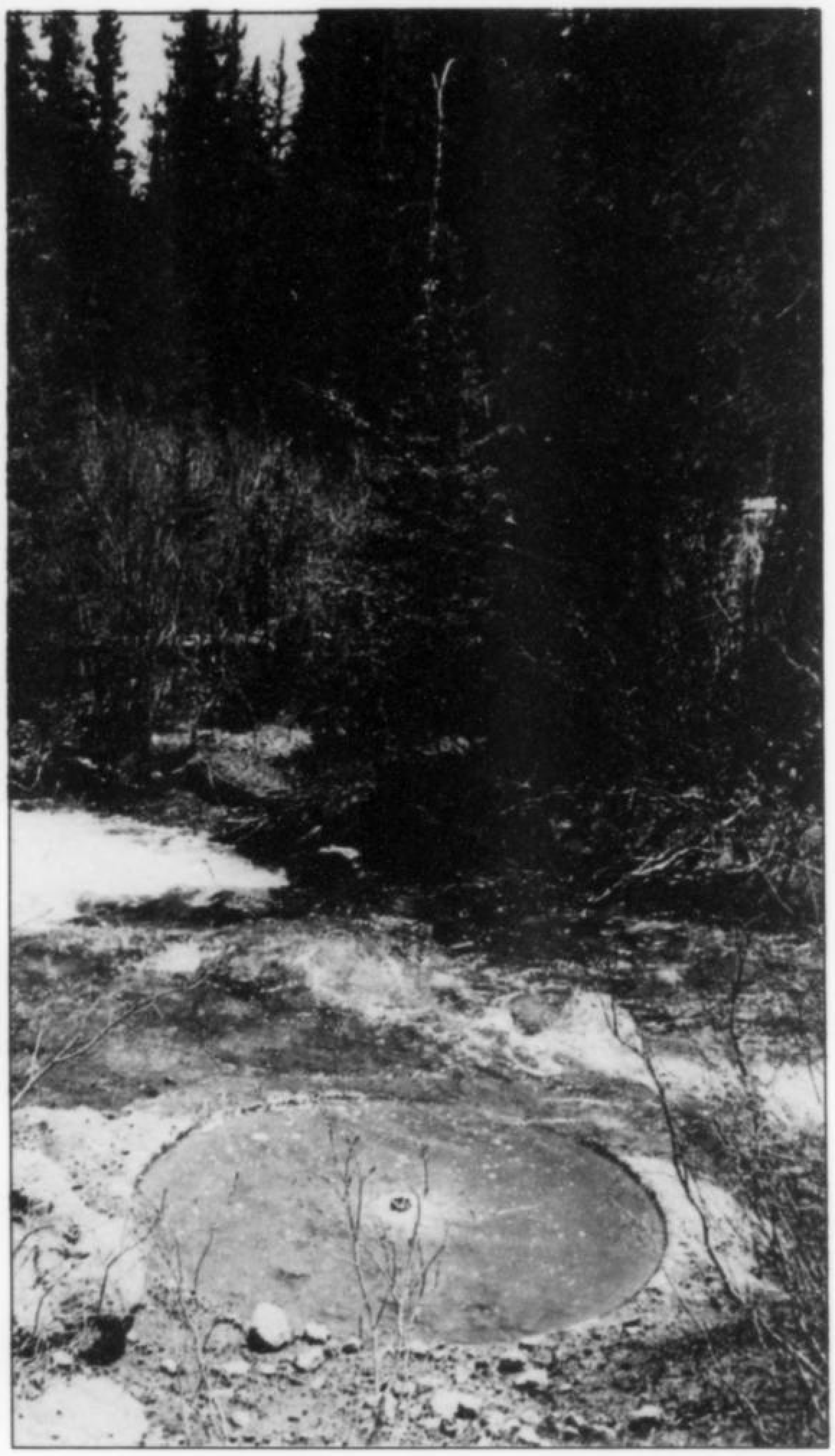


Figure 6. **Hand-hewn *arrastra* from the early days of lode gold mining in Buckskin Gulch, ca. 1863. Photo by Bryan Lees.**

extended period of simultaneous exploration and development. Limited production began in 1924 and continued intermittently through 1929. Miners conducted all work through a new lower tunnel—the present Sweet Home tunnel—driven about 50 feet west of the Combination tunnel.

During those six years, miners drove the Sweet Home tunnel and several crosscuts a total distance of 1,626 feet. They shipped 360 tons of hand-cobbed ore with a gross value of $30,000 to a nearby Leadville mill and smelter. Most of that production was mined in 1925, when a single stope yielded 16,000 troy ounces of silver—the best the Sweet Home mine would ever do on silver.

The year 1925 was remembered not only for the profitable stope, but for a major discovery of rhodochrosite. In his 1933 report, Beeler wrote:

> Crosscut No. 1 [renamed Crosscut No. 2 in 1991] was run east for a total of 442 feet, with three short drifts. The main interest of this work was the remarkable showing of rhodochrosite found at intervals.

Miners following a narrow vein in the second drift of the second crosscut blasted into a series of crystal-lined cavities. Turning the drift sharply, they followed the cavities for 30 feet, recovering a substantial number of matrix plates with fine rhodochrosite crystals. Beeler noted, "This material was specimen ore and much of it was sold to curio dealers and for museum exhibits, one lot in particular going to the Institute of Plant Research, at Yonkers, New York."

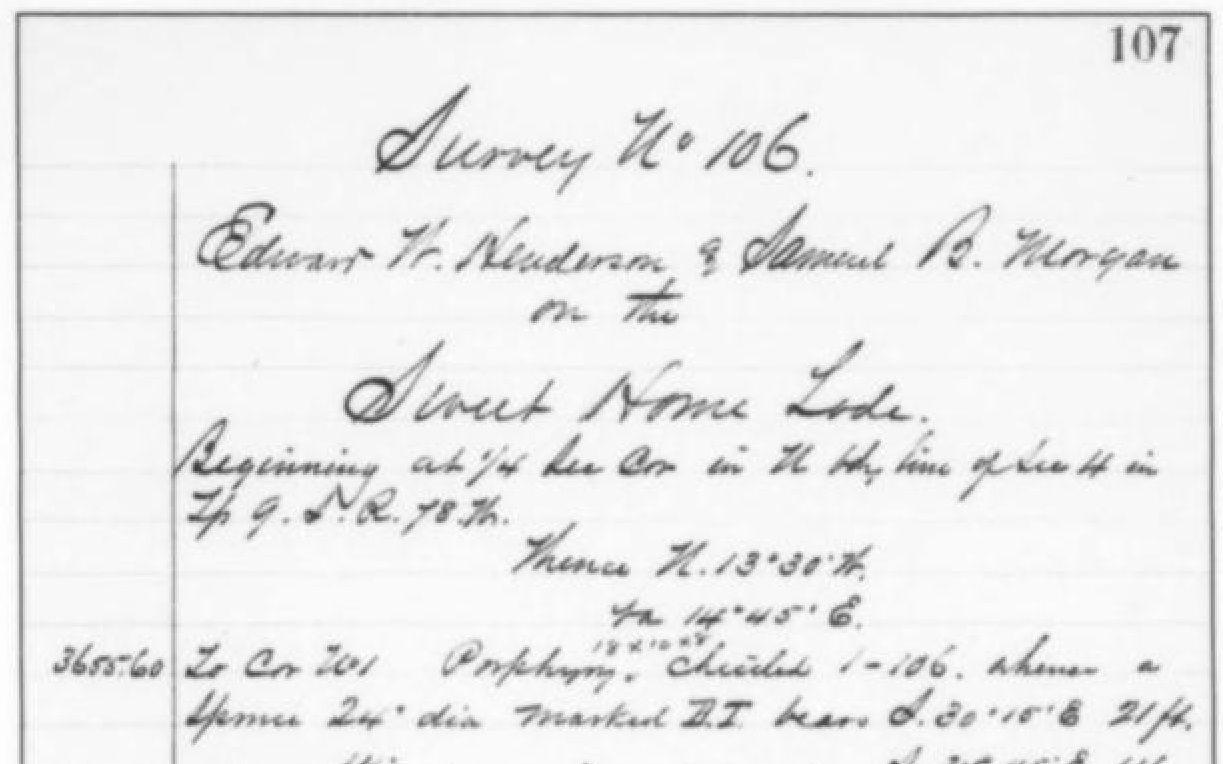
Mine owners sold at least two lots of crystals, one for the sum of $900. Among the specimens were several large, 24-inch matrix plates with numerous rhombohedrons of gem-quality rhodochrosite resting on beds of clear needle quartz. Some plates found their way to the American Museum of Natural History and were included in the museum's J. P. Morgan exhibit at the French National Museum in Paris. Other rhodochrosite specimens from the 1925 find went to the Smithsonian Institution and major museums in Sweden, Germany, England and Switzerland. After 1925, museum curators recognized the Sweet Home mine as a leading source of fine rhodochrosite.

Interestingly, "high-grading"—the illegal or unauthorized removal and sale of crystals—was not a problem in 1925, for no one yet fully understood or appreciated the quality or potential value of Sweet Home mine rhodochrosite. But high-grading would play a big role in the Sweet Home mine's future.

After 1925, production waned and the Sweet Home resorted to its old money-losing ways. The mine remained active solely because of E. C. Spray's unbridled optimism. Local Alma miners, facing high district unemployment, considered Spray a "pigeon," a Denver businessman who rarely visited the mine, yet who continued to write checks for its operation.

Between 1922 and 1929, Spray had not only kept the mine

Figure 7. **The first survey of the Sweet Home mine in 1873, showing the survey patent number at the top—"106", one of the earliest patented mining claims in the United States.**



107

Survey No. 106.

Edward H. Henderson & Samuel B. Morgan on the

Sweet Home Lode.

Beginning at 1/4 Sec Cor in N. bdy line of Sec 4 in Tp 9. S. R. 78 W.

Thence N. 13° 30' W.

Va. 14° 45' E.

3655.60 To Cor No 1 Porphyry chiselled 1-106. whence a Spruce 24 in dia marked B.T. bears S. 30° 15' E 21 ft.

Cor No 1 Sur No 107. bears S. 58° 30' W. 304 ft.

Thence N. 63° 3' E.

2700. Cor No 2 Porphyry

Thence S. 26° 57' E.

50. . . 3. Porphyry

Thence S. 63° 3' W.

2700. . . 4. Porphyry

Thence N. 26° 57' W.

50 . . 1. beginning.

Fred C. Morse
Dep Sur
Surveyed August 20. 1873

Buckskin Joe Mining Dist
Park County.

Figure 8. **View showing altered and mineralized outcrops (yellow-brown) above the Sweet Home mine, 1992. Photo by Chauncey Walden.**

active, but went from major shareholder to Vice President to sole owner by acquiring the Sweet Home Gold and Silver Mining and Milling Company, Inc. a portion at a time. Full control was gained in 1929 when, at a sheriff's sale at the Fairplay courthouse, Spray purchased the few shares of the Sweet Home group that remained outstanding. Spray's now wholly owned company held the mining rights to 15 adjoining claims, the Sweet Home fraction and Sweet Home claims being the most significant among them. In the years to follow, Spray's company would acquire the adjoining Winnie, Bushwacker, Niagara Lode and Grover Cleveland claims to bring the count to today's 195-acre plat of 19 claims.

Spray continued to support the otherwise unemployed Alma miners by funding sporadic exploration during the 1930's. During World War II, Spray again kept the mine active, this time by leasing it out for tungsten exploration.

Table 1. **Claims comprising the present-day Sweet Home property.**

Claim Name	*U.S. Mineral Survey No.*	*Claim Name*	*U.S. Mineral Survey No.*
Sweet Home Lode	106	Kasel Lode	20,504
Pulaski	107	Silent Friend Lode	20,504
J. G. Blaine	766	Social Fund Lode	20,504
Magnet	6437	Spray Lode	20,504
Grover Cleveland Lode	7278	Wedge Lode	20,504
Winnie Lode	7288	Blue Bird Lode	20,507 A
Detroit City	8413	Daniel Lode	20,507 A
Enterprise	8413	Sweet Home Fraction	20,507 A
Crackerjack Lode	20,504	Bushwacker	20,591
		Niagara Lode	20,591

Figure 9. **Ed Snell's burro pack train in "downtown" Alma, Colorado, ca. 1900. Photo by Galloway.**

Figure 10. **Visiting ladies at the London mine, near Alma, Colorado, ca. 1904. Powless photograph.**

On-and-off exploration continued through the 1950's. Lessees occasionally shipped small lots of hand-cobbed silver ore, while also collecting rhodochrosite specimens and cleavage fragments which they traded for drinks in the Alma bars.

Activity picked up in 1963 when Douglas Brothers, a small development company, leased the mine in hopes of replicating the 1925 silver "bonanza." The stope that yielded the 16,000 ounces of silver in 1925 had since collapsed, and Douglas Brothers planned to drive a 100-foot-long bypass around the caved stope to access high-grade ores which they thought might exist on the other side.

One of the summer mine workers was Hershal Ellyson, Clarence Douglas's grandson, who was destined to play a major role in the future of the Sweet Home mine. Ellyson was a high school student with an interest in mineralogy and, especially, rhodochrosite. After studying previously-mapped Sweet Home rhodochrosite occurrences, Ellyson predicted the existence of other crystal pockets.

Meanwhile, Clarence Douglas, the elder Douglas brother, died in December of 1964, delaying the planned mine work. E. C. Spray died two months later, passing the entire Sweet Home property on to his widow, Eleanor Bramkamp Spray. Eleanor Spray would soon pass the Sweet Home mine property on to her nephew, Leonard Beach.

John Soules, a Texan with most of his savings invested in the Douglas Brothers' lease venture, took over the lease and moved to Alma to attempt to save his investment. Soules' miners completed

***Figure 11.* Sweet Home mine outbuildings, 1933. Photographer unknown.**

the stope by-pass in 1966, but failed to find any significant amount of high-grade silver ore. Soules, quickly running out of money, saw little choice but to shut the mine down and return to Texas. Aware that rhodochrosite specimens had now appreciated in value, he recalled young Hershal Ellyson's prediction of other rhodochrosite occurrences. Soules decided to gamble his remaining capital on "a couple of rounds" to test Ellyson's theory.

Soules and a hired miner, Warren Good, drilled and shot an overhead round near the vein they were following in the main stope in the third crosscut. Just a few feet from where the 1925 miners had stopped, the round uncovered a small crystal-filled cavity about the size, as Soules described it, of a "No. 3 washtub." From the cavity Soules recovered a dozen fine rhodochrosite crystals. The best is a 2-inch, euhedral, gemmy rhomb decorated with blue fluorite crystals that is currently valued at more than $10,000. Other specimens, still in possession of the mine owners, are now valued as high as $1,500 each. The "washtub cavity" also yielded more than 100 rhodochrosite cleavage fragments.

After John Soules returned to Texas in the fall of 1965, subsequent events at the Sweet Home mine become unclear, for those involved offer conflicting accounts, or refuse to comment at all. Soules left the Sweet Home mine inactive, or so he thought. However, Warren Good, his contract miner who may not actually have been on anyone's payroll, seems to have continued free-lance exploration of the "washtub cavity" area. When Soules returned on a weekend trip six weeks later, he was surprised to learn that Good had blasted into a spectacular rhodochrosite cavity.

Only John Soules and a handful of other individuals ever saw this cavity. According to Beach (1988), Soules described it as 7 feet high, 4 feet deep, and 2 feet wide:

> Boy, there were some beautiful crystals in there; talk about a beautiful sight, [said Soules]. The way I was looking in, they looked as thick as could be. There could have been hundreds of rhodochrosite crystals in there, some of them very large. The entire cavity was just studded with crystals.

In the dead of winter in early 1966, Soules headed back to Texas. Six weeks later, he again returned to the supposedly inactive, snow-bound Sweet Home mine, this time to learn that Warren Good had cleaned out the entire crystal pocket, purportedly in a period of just three weeks. Good claims he decided to market the specimens himself and later split the proceeds with Soules (Jones, 1993). Leonard Beach, currently the majority owner, states that Soules never received a payment, and that Good had high-graded the pocket, certainly destroying many fine crystals in a heavy-handed rush-job to clean it out (Beach, unpublished prospectus, 1988).

One of the first individuals to learn of Warren Good's rhodochrosite find was Ed McDole. McDole was one of the last of the true rogue mineral dealers. Using the trunk of his Lincoln Continental as a "showroom," McDole followed a loose circuit across the nation, visiting shows and other dealers. McDole, who had a legendary knack for acquiring nice specimens cheaply and turning a profit quickly, dealt only in cash. McDole's role in the marketing of the 1966 Sweet Home mine rhodochrosite is uncertain, but he is believed to have purchased a number of fine specimens from Warren Good. Then, in his flamboyant manner, McDole displayed them to various dealers, in the process calling considerable attention to the Sweet Home mine.

Denver rock shop owner Denzel Wiggins heard of the superb specimen later named the "Alma Queen" and reported its availability to Denver mineral dealers George Robertson and Merle Reid. Robertson and Reid immediately drove to Alma on a Saturday afternoon. Displaying the specimen on the bed in a motel room, Good agreed to sell it for $2,500 in cash.

Scraping together that much cash on a 1967 weekend wasn't easy. But Robertson returned to Denver and succeeded in cashing three personal checks at three different supermarkets. Returning to

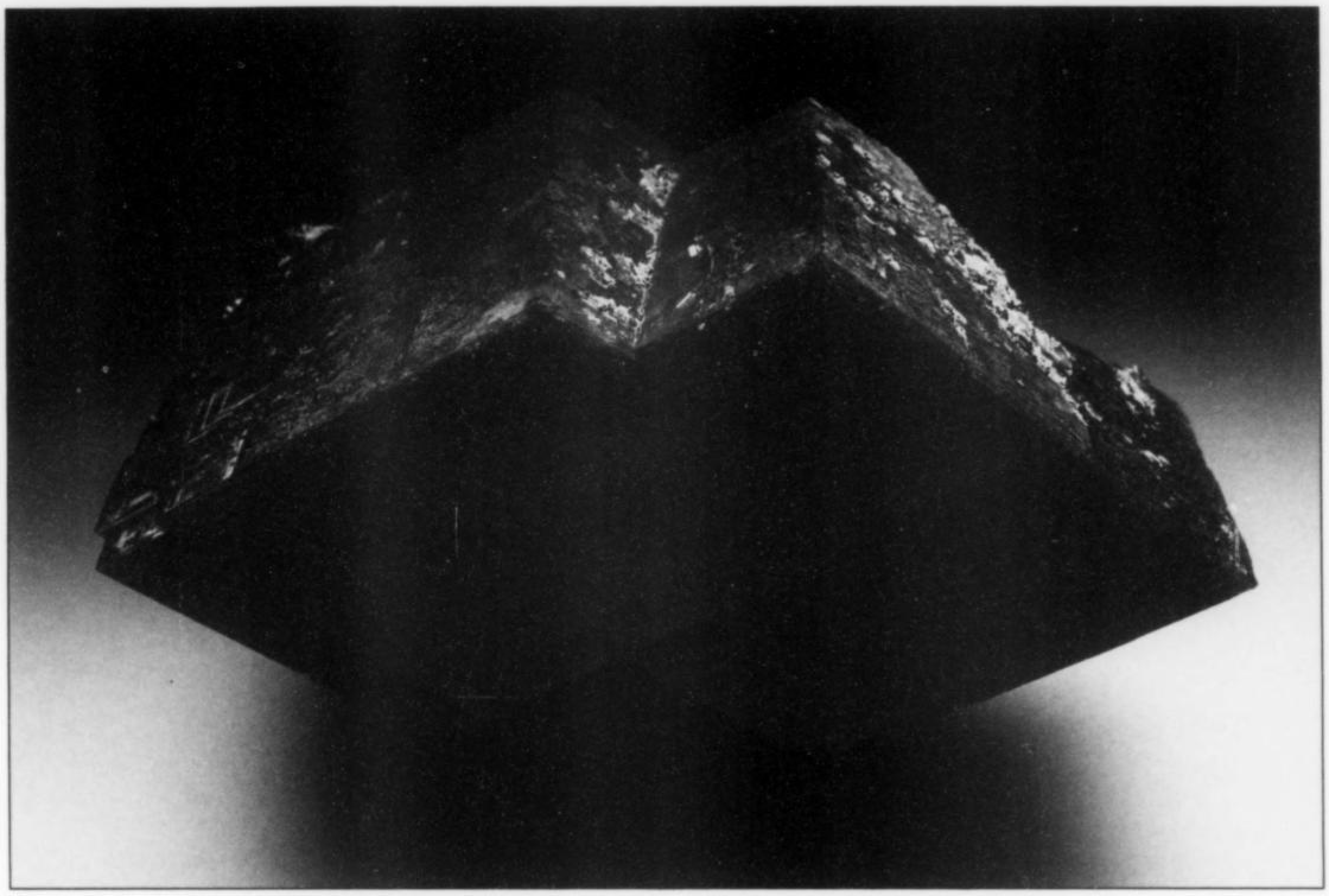


***Figure 12.* The Taylor rhodochrosite, 11 cm, in the collection of the Denver Museum of Natural History. Photo by Wendell E. Wilson.**

Alma late that afternoon, he and Merle Reid became the second owners of the Alma Queen. Warren Good, now with a pocket full of cash, wasted no time saying good-bye to his wife and family. Accompanied by his girlfriend, Good left Alma and was never seen again.

Ed McDole was so impressed with the 1966 Sweet Home specimens that he negotiated to lease the mine property. But his plan to reopen the mine for rhodochrosite specimen production was cut short by his death in 1968.

Meanwhile, Robertson and Reid insured the Alma Queen for $10,000. George Robertson gave the Alma Queen its first public showing, displaying it in a special glass case at the 1967 Las Vegas Gem & Mineral show. Norm Dawson also displayed numerous other 1966 Sweet Home mine specimens from his show booth, all possibly acquired from Ed McDole.

At its first public viewing, the Alma Queen was a show-stopper, attracting the attention of such top collectors as John Patrick, Rock Currier and Dave Wilber. Everyone knew it had been repaired (the big crystal had broken loose in the pocket and had to be re-attached) but no one cared. An awed Patrick described the Alma Queen as nothing less than "the finest mineral specimen in the world."

Several months later, Dr. Peter Bancroft flew to Denver to study the Alma Queen. After one look, Bancroft was determined to own it. He worked out a trade with Robertson and Reid, taking the Alma Queen in return for fine specimens of Bolivian phosphophyllite, a mineral that was then considerably more desirable than rhodochrosite. Bancroft gave up two cabinet specimens, twenty-five thumbnails, and one "good" miniature of phosphophyllite. The value of the trade was estimated at $6,500.

It was then that Bancroft named the stunning rhodochrosite specimen the "Alma Queen." In 1973, Bancroft published *The World's Finest Minerals and Crystals*, a photographic collection of 78 minerals selected by a distinguished panel of experts as the best of their species or type. The book's cover, a dramatic photograph of the Alma Queen, by then also known as the "Bancroft rhodochrosite," stirred the imaginations of mineral collectors around the world.

***Figure 13.* Leonard Beach, 1992, at the Sweet Home mine portal.**

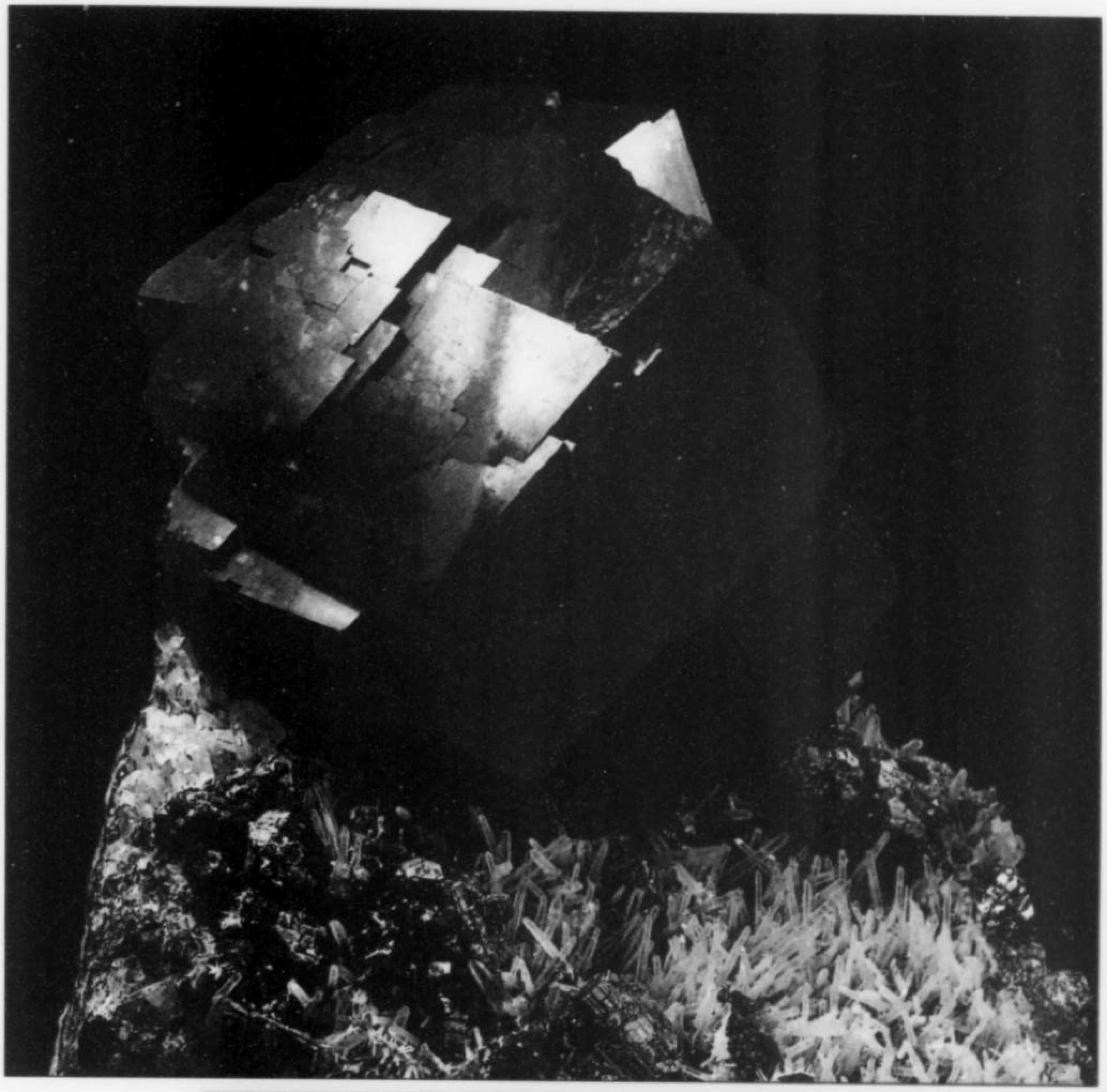


Figure 14. The "Alma Queen" rhodochrosite, Houston Museum of Natural History collection. The main crystal measures 10.0 cm. Photograph by Wendell E. Wilson.

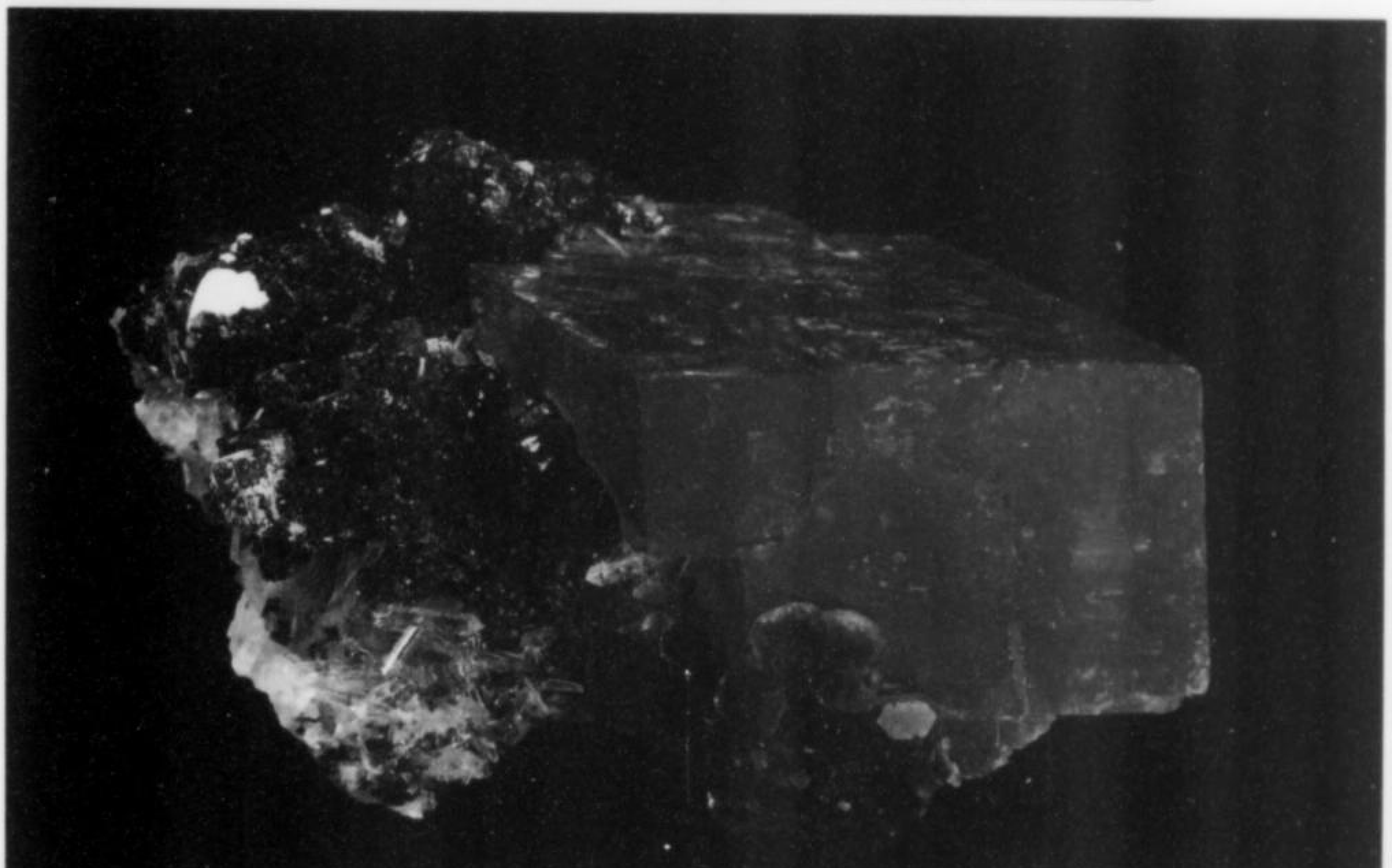


Figure 15. Rhodochrosite specimen, 7 cm, found New Year's day, 1976, by Norm and Roger Bennett. Collection of Bryan Lees; photo by Bernie Kowalski.

In 1974, Dave Wilber purchased a large part of the Bancroft Collection, primarily to acquire the Alma Queen. The total price of the collection was $400,000, $85,000 of which was attributed specifically to one specimen—the Alma Queen.

Wilber then sold the Alma Queen to Ed Swoboda in 1979 in a cash-trade deal that involved a Rolls-Royce. In that deal, made just 12 years after Warren Good had received $2,500 for the specimen, the Alma Queen's value had rocketed to an astounding $185,000.

In 1982, Swoboda sold the Alma Queen to Texas oilman Perkins Sams for $85,000. The lower value clearly reflected a slowing and stabilizing trend in mineral specimen market growth. After the wild price spiral of the 1970's, many collectors clearly wished to catch their breath and more cautiously assess the state of the market.

But Perkins Sams had acquired the Alma Queen at a most inopportune time, for his personal wealth was tied to the fortunes of the oil industry. Oil prices had begun collapsing in 1981 and Sams was soon forced to liquidate his material assets. In 1984, Sams sold his entire 1,200-piece collection, including the Alma Queen, to the Houston Museum of Natural Science. The Alma Queen became and remains a showcase exhibit at the Houston Museum of Natural Science where, in 1990, it was valued at $250,000.

Another superb specimen from the 1966 recovery is the internationally famous, 4-inch, "twinned," deep red, gemmy rhodochrosite displayed in the Coors Mineral Hall of the Denver Museum of Natural History. That specimen is now valued in excess of $200,000. It is not surprising that some consider the mining, recovery, and sale of the 1966 Sweet Home rhodochrosites as one of the more notable incidents of high-grading in mining history.

The profusion of rhodochrosite that hit the market in 1966 clearly established the Sweet Home mine as the world's leading source of fine rhodochrosite. The superb specimens made the mine familiar to a legion of gem and mineral dealers, casual collectors, and even rockhounds. The 1966 recovery also called into question the classification of the mine itself. Was the Sweet Home still a silver mine? Or had it become a rhodochrosite mine?

The notoriety attracted considerable attention from other high-graders. Most were "rockhounds," content to sift through the Sweet Home mine dumps for small, iron-stained, abraded matrix specimens and cleavage fragments. Some high-graders, however, were considerably more ambitious. In January 1977, Norm and Roger Bennett snowmobiled to the Sweet Home mine on New Year's Day for a bit of underground high-grading. In Crosscut No. 2, near the location of the 1925 rhodochrosite find, the Bennetts pounded on the mine walls to listen for "hollow" sounds that might indicate cavities. They located and opened a beautiful, small pocket that measured about 2 inches wide, 2 feet long, and a foot deep. Many of the specimens recovered from the pocket didn't reach the market until 1990, when 3-inch matrix sections with perfect, deep red, 1-inch rhombs sold for as much as $15,000.

In the early 1970's a group of museum curators suggested to majority owner Leonard Beach that the only way to obtain more specimens would be to mine both silver and rhodochrosite. Theoretically, they believed that income from the mining of selected silver ore might cover operating costs and thus finance a search for rhodochrosite.

Mineral dealer Richard Kosnar formed the Intercontinental Mining Corporation with John Saul and was the first to work the mine specifically for rhodochrosite. Since his youth, Kosnar had been intrigued by the Sweet Home rhodochrosite specimens at New York's American Museum of Natural History. The possibility of someday working the Sweet Home mine became one of his primary reasons for eventually relocating to Colorado.

In 1977, Kosnar leased the Sweet Home mine. The following year, Kosnar's crew, working on a shoestring budget that did not even permit muck removal, drove a raise on the same fissure associated with the 1966 rhodochrosite find. Every round yielded mineralization, including quantities of massive rhodochrosite and, occasionally, whenever fractures had provided space for growth, small, well-developed rhodochrosite crystals. One good pocket of very fine rhodochrosite rhombohedrons was sold in Paris. Kosnar purchased back many Sweet Home specimens from high-graders, including 1-cm tetrahedrite crystals, ruby-red hübnerite crystals, twinned stromeyerite, and good crystals of goyazite, svanbergite and fluorite (Bancroft, 1984).

In 1980, mine owners leased the Sweet Home mine to AMAX Exploration, the exploration arm of the mineral giant, AMAX, Inc., then the world's leading producer of molybdenum. Encouraged by a surging molybdenum market, AMAX aggressively sought molybdenum properties and took a hard look at the Alma mining district. Mine owners believed that AMAX was about to exercise its option to purchase the Sweet Home mine and adjacent properties in 1981 (Beach, 1995, personal communication). Acquisition, possibly followed by mass mining, would have meant the end of the Sweet Home mine. However, after the molybdenum market crashed late in 1981, AMAX allowed its lease to expire.

Although the Sweet Home mine remained inactive during the 1980's, it was not forgotten. When portal timbers collapsed, mine owners refused to rebuild the tunnel in hopes of discouraging the incessant underground high-grading. For Leonard Beach, the Sweet Home mine had become quite an education. Professionally, Beach first managed the family's Denver milk business before becoming involved in insurance. In the 1970's Beach learned the basics of hardrock mining by helping with the Kosnar operation. Later, in the 1980's, when it became clear that rhodochrosite represented the Sweet Home mine's future, Beach learned the basics of mineralogy and mineral collecting.

In 1987, Leonard Beach began actively marketing the Sweet Home mine to specimen miners. Several groups, both corporate and individuals, expressed serious interest. In the end, it was Bryan and Kathryn Lees, mineral dealers and operators of *The Collector's Edge* in Golden, Colorado, who most impressed Beach with their competence and excellent professional recommendations. In 1990, after demonstrating the ability to fund a serious rhodochrosite mining project, Sweet Home Rhodo, Inc. (a consortium of investors led by Bryan and Kathryn Lees) leased the property from Leonard Beach.

The rest is also history. The spectacular rhodochrosite specimens that Bryan and Kathryn Lees and their mine crew have recovered in the 1990's have received worldwide publicity. The cumulative value of the rhodochrosite specimens recovered from the Sweet Home mine over the years probably exceeds $5 million, and the mine is clearly the world's premier source of fine rhodochrosite. All in all, that's not a bad record for a "failed" silver mine.

My thanks to Joel Bartsch, F. Leonard Beach, Bryan Lees, George Robertson and David Wilber for providing some of the above historical accounts.

New Operations at the Sweet Home Mine 1990–1997

Thomas Moore
15 Lakeview Drive
Niantic, Connecticut 06357

INTRODUCTION

There they were, looming, straight up and all out-of-scale, amazingly beautiful, and almost intimidating: the "Alma King" and "Alma Rose" rhodochrosite specimens from the Sweet Home mine in their exhibit case at the Tucson Gem & Mineral Show in 1993. There had been foreshadowings as far back as the 1991 Denver Show, but after this 1993 Tucson debut there could be no mistaking the magnitude of the Sweet Home story that was unfolding. Like everyone else, I was stopped in my tracks by the "King" and the "Rose"; like everyone else, I gaped, and then began scrambling for scraps of information and explanation to pass on in my show report (vol. 24, no. 3). But I also appreciated how big a job it would be to learn anything like the whole story.

Thus it was a very great pleasure to make two summer trips, in August of 1994 and 1995, to Colorado to learn the collecting tale in something like its full scope. My account will frequently quote from printed sources and from interviews with some of those who have been key Sweet Home players. But as much as the story "belongs" to any of these particular people, it belongs to the whole mineral collecting community which has indirectly participated, via its eagerness and support, in this, one of the most exciting of all recorded mineral-digging sagas. Collectors alive today are unlikely ever again to see anything as thrilling. Here is how it went for seven busy years (1991–1997) in the history of the Sweet Home mine.

BACKGROUNDS AND BEGINNINGS

The story began in the imaginations of Bryan and Kathryn Lees of *Collector's Edge Minerals, Inc.* in Golden, Colorado. The first glimmers occurred in the summer of 1989, when the Lees were developing (with Dennis Wilson) the Stoneham, Colorado, blue barite locality. One night while Bryan and George Robertson sat staring into a nighttime campfire at the Stoneham workings, George said he knew of a rich rhodochrosite vein still exposed from the work in the 1960's. Bryan soon discovered that a group led by mine owner F. Leonard Beach was already having notions of reviving the mine, and in fact had developed a fairly detailed mining plan.

In 1968, Beach acquired a ⅝ths ownership share of the mine from his Aunt Eleanor. At the time he was without knowledge of mining, mineralogy or specimen collecting. The giant molybdenum-mining company AMAX had the Sweet Home under lease, and Beach thought that he might have a rich ore mine among his assets. But, fortunately for rhodochrosite enthusiasts, molybdenum prices crashed, and AMAX's option to the mine was allowed to lapse.

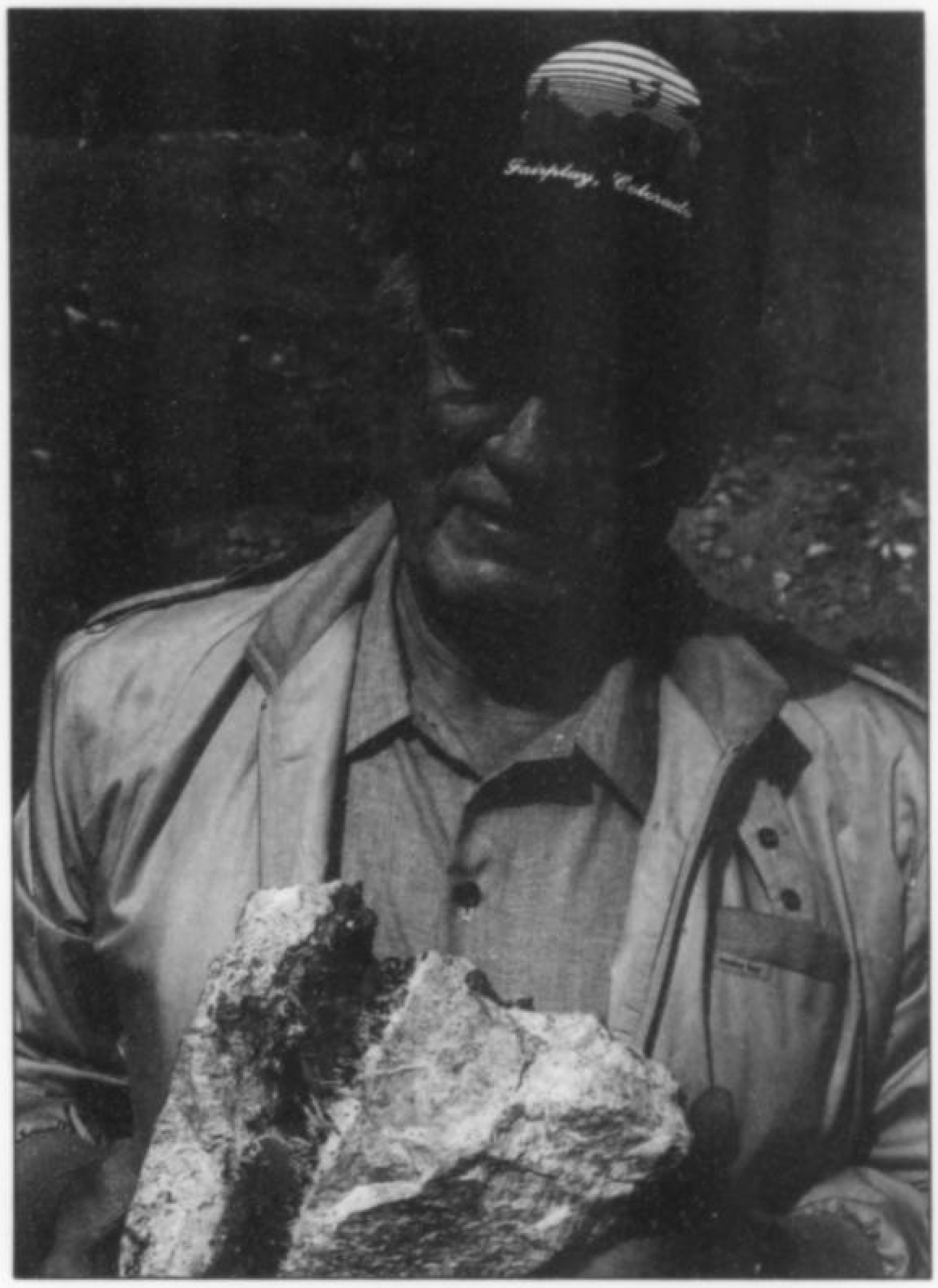


Figure 16. Leonard Beach at the Sweet Home mine in 1988, showing a piece of vein material with rhodochrosite to a field trip group from Denver. Photo by Karen Wenrich.

In 1977, Beach played a role in a brief specimen-mining effort at the Sweet Home and began then to envision a future for the mine that had nothing to do with molybdenum or even silver ore. Upon learning that the great "Bancroft Rhodochrosite" specimen (also called the "Alma Queen") dug in 1966 had been valued at $125,000, Beach set out to educate himself about specimen mining and serious mineral collecting. Visiting mineral shows, reading much and talking with people whom he increasingly came to regard as potential partners, Beach gradually put together his plan, and in due course wrote a thorough prospectus. (A copy of this

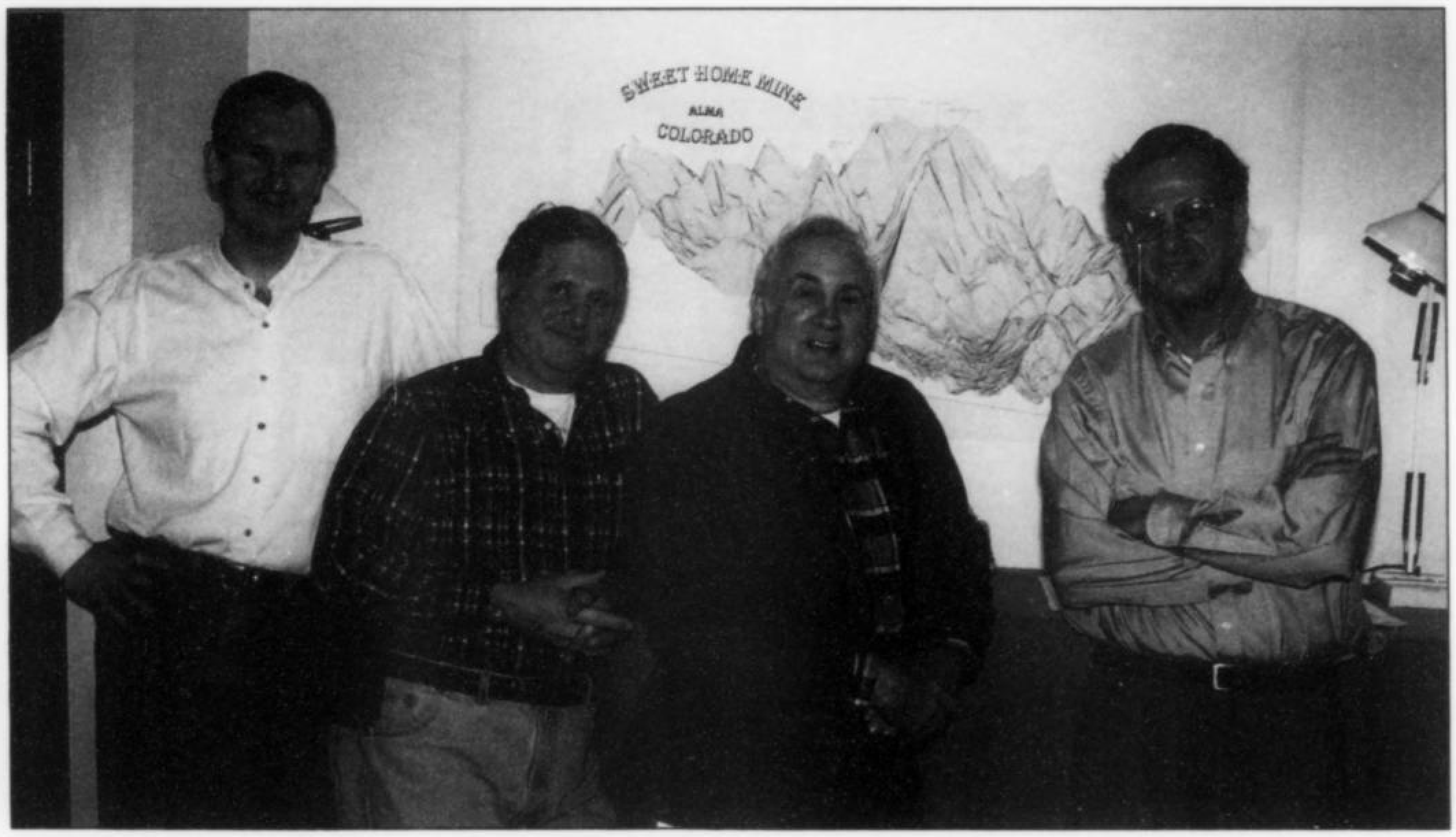


Figure 17. **Sweet Home mine investor group (from right): John Lucking, Gene Meieran, Marty Zinn and Bryan Lees. Photo by Bernie Kowalski.**

1990 prospectus, it is interesting to note, recently sold as a collector's item for around $200.)

About this early plan of his, Beach is proudest of two things. First, quite on his own, he came firmly to the conclusion that the Sweet Home's real future was as a specimen mine; by no means could it ever be profitable as an ore mine. Second, he presented in his prospectus a theory that the mine's crystallized pockets would be found occurring *en echelon* in tension fractures, so they might be looked for along strikes from earlier finds. This is a much less sophisticated model than the current understanding from which Sweet Home Rhodo, Inc. works (see later), but it was a very intelligent guess for a man self-taught in the field.

Enter Bryan Lees and a pioneering group of investors. Chief in enthusiasm among these were Marty Zinn and Gene Meieran. Also associated with Bryan, by now, was mining engineer Bill Kazel. Six months or so of meetings and negotiations (late 1990, very early 1991) ensued. At times, the parties were on the point of chucking the whole thing and walking away, so great seemed the personal, legal and technical obstacles. But by the spring of 1991, an agreement was reached, a lease secured, and a quest for further investors energetically launched. *Sweet Home Rhodo, Inc.*, as the new corporation was called, was on its way.

Early in the year, Bryan sent a detailed proposal to several prospective investors. Seven of them (i.e. six besides the Lees) were each asked to invest $50,000, including an immediate $1,000 in "earnest money," for a five-year mining project with a subsequent renewal option. Mining was to begin in April and would go on intensively for six months in each of the five seasons. Of the total investment capital of $350,000, about $250,000 was to be used in the first year alone, mainly for the expenses of getting the mine in working condition again. The eventual income from specimen sales was to combine with the remaining $100,000 of initial funding to pay for the second year of operations. After that, the mine would become (according to the proposal) self-supporting.

There could be no denying that the investment was a very large gamble. But the Lees offered the educated projection that once specimen production got seriously underway the average gross income from sales could be between $700,000 and $1,000,000 yearly. Naturally, this estimate generated much discussion and some skeptical disputation. Bryan's research on the mine's history, though, enabled him to argue that, to quote from the proposal, "The mine produced at least two million dollars worth of rhodochrosite during the past 70 years [mostly from the "bonanza" strikes in 1925 and 1966] out of two relatively small (about 50 feet long) stopes. It is this ratio of relatively small working area to high rhodochrosite production that makes this property an attractive target for mineral specimen exploration." Precisely—and the initial estimate of sales has in fact turned out to be quite close to the mark, even though, as expected, the first mining season yielded little to offset the high start-up costs. The great pockets of the 1992 season

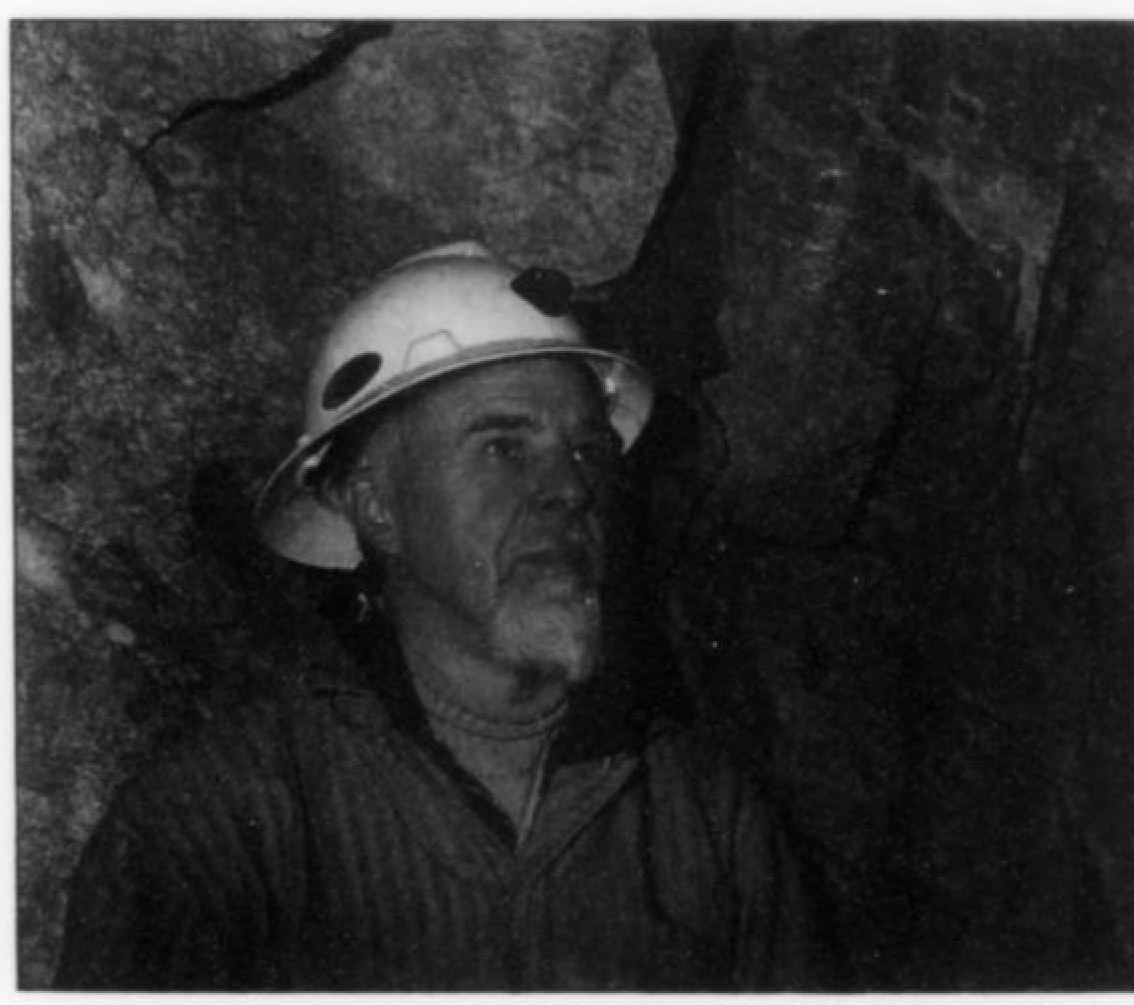


Figure 18. **Vice President and mine manager Bill Kazel examines mineralized structure underground at the Sweet Home mine. Photo by Ed Lewandowski.**

were what really vindicated, at last, that million-dollar dream . . . but this gets ahead of the story.

By the 1991 Tucson Show, the Lees had secured their six outside investors and felt ready to start full-scale mining on June 1. But a last-minute demonstration of the project's fragility was still to come; in mid-April, three of the original investors abruptly withdrew their financial support. In the ensuing panic, the Lees did not ask the remaining investors for still more money; instead, Bryan moved to the mine to do, himself, some of the heavy work he'd intended to pay crew members to do. As no early pockets were hit, this was financially and emotionally the diciest of times. Hindsight permits the luxury of a line or two here to salute the courage of the four investors who hung in faithfully through that initial season: the Lees themselves, Marty Zinn, Gene Meieran, and John Lucking. All of these are now seeing their investments repaid, not only with interest, but with what must be a most satisfying sense of having crucially staked some very major American specimen-mining history.

Before a season-by-season account of that history commences, though, some other players should be introduced. Bill Kazel, a free-lance mining contractor, is now full-time mine manager at the Sweet Home mine. He first came to know the mine during its short re-awakening in 1977, when he supervised the clean-out of the old caved-in portal and leased equipment for the venture. These days, he is frequently to be seen bringing new equipment up to the mine in his truck, repairing or contracting for the repair of broken equipment, advising on mining procedures, and generally trouble-shooting. My durable image of Bill is of a slender, brusquely quick man in blue jeans struggling mightily (in August 1995) to get the mine's first outside phone line fully wired-in and operable in the mine shed by the portal.

Helping Bill in this effort was Roy Rizzardi—mine foreman, mechanic and main "outside" man on duty each day. A veteran of the Battle of the Bulge and of the postwar occupation of Austria, Roy is also a veteran of Colorado mining life, almost continuously since he entered the profession in 1941 at age 14. The appeal of hardrock mining, to this archetypal old-timer, is such that "there's nothing at all I'd rather do if I had to start over."

Mine geologist Dean Misantoni started as a part-time consultant for Sweet Home Rhodo, Inc. For seven years he was chief geologist at the London gold mine, just over the ridge from the Sweet Home. This mine closed in 1991, and Dean signed on full-time with Sweet Home Rhodo, Inc. at the start of the 1994 season. It is to Dean's early geological mapping that the Sweet Home operation owes its first successes; it was his data which first hinted at where and how the crystallized pockets might be chased.

Shift miner Scott Betz, though born and raised on a wheat farm in Kansas, has been a full-time hardrock miner since 1976, when he began at Colorado's Climax molybdenum mine. Although he does not wax loquacious on his profession (best thing about hardrock mining? "The money . . ."; worst thing about it? "The work . . ."), he is dedicated completely to this very difficult occupation.

Bryan Lees has his own opinions on why miners pursue such work:

> When you ask a miner, "why do you do this?" he doesn't always have an immediate answer. Some look forward to seeing what lies ahead just past the next few feet of rock. Others simply like to blast rock. Some enjoy the challenge of the hard work, testing themselves daily against its physical demands. Many are drawn to the solitude of working in the total darkness and isolation of underground. Although a few do it for the money, it becomes plain that there's something about mining that gets into their blood.
>
> We use outdated mining techniques. . . . Our primary tool is the jack-leg drill. Developed around the turn of the century, the drill is manipulated by hand and creates one hole at a time. It is heavy, noisy and creates large quantities of dust. A driller can "feel" the rock he is moving: its hardness, texture and potential for open space. Mining with jack-leg drills is considered by many to be a classic technique. Today, there are few classic hardrock miners who possess the skills and the experience necessary to extract crystals. Fewer still are learning these skills for the future. In the first half of this century, there were tens of thousands of such men. Today, in Colorado, we have a difficult time fielding a crew of six each year. Modern, large-scale mining equipment has replaced the need for the classic miner.

But Jim Smith, a fourth-generation miner, says that he's gotten into fights in bars over the question of whether it's better to use a jack-leg or a stoper drill to go up in raises; Jim knows that he is a "classic" himself, and enjoys the fact.

Many miners have participated in the Sweet Home project through the years. Graham Sutton, who helped re-open the mine, worked through the 1991 season. Rory and Carrie MacDonald worked the 1991, 1992 and 1993 seasons. Mike Warren started working at the Sweet Home mine in 1993; with one year off in 1995, he is there still. Dan Stephens, a miner from Telluride's Smuggler-Union mine, worked during the 1994 season. Jim Smith and Mike Savage came on for the 1995 season. Rodney Orton also came on in 1995 and is working still. Tony Sherrill, a new member of the Sweet Home team, started in 1996. It is Scott Betz who is the old-timer now, having worked at the Sweet Home since 1992 and working there still (fall 1997).

THE 1991 SEASON

During those early, parlous months of '91, in order to keep interested parties interested, Bryan Lees created a newsletter which he named *Sweet Talk*. The five numbers of "volume one" popped up at irregular intervals between May and December of 1991; the little bulletin provides the only up-close account of the earliest trials and growing pains of Sweet Home Rhodo, Inc. Here are some excerpts from issue number one:

> May 29, 1991
>
> Dear Interested Observer,
>
> It has come to my attention that I have been somewhat infrequent in disseminating information about our Sweet Home project. The only thing I can say in my defense is that we have been busy as hell mobilizing the entire effort. It is now obvious that my "shotgun" approach of informing everyone about our progress is painfully lacking in showing the overall picture. THUS, OUR NEW RAG SHEET! *SWEET TALK!* . . .
>
> Funding has been arranged through four investors . . .
>
> Much effort went into the actual formation of the corporation. Many options were covered with attorneys and CPA's. Sub-Chapter S status was settled upon with the resulting legal and technical details worked out. The name "Sweet Home Rhodo, Inc." was chosen . . .
>
> During the incorporation process, mine planning and permitting were proceeding. The City of Alma water permit was finally issued last week. The next toughest permit was the MLRB (Mined Land Reclamation Bureau). . . . Our MLRB status shows us as prospectors. This status saved posting a bond for the time being. . . . The permit will be reviewed again next year. . . .

Our first trip to the mine this year revealed a clear but soggy road. . . . It will take about two weeks before we can take in heavy equipment. However, two mine crews are busy securing the on-site building.

Last week, Public Service granted our request for electricity at the mine. This will dramatically reduce our power costs. . . . On-site electrical shut-offs and transformers will be installed during the next week.

Because we have electricity, we can acquire an electric-powered air compressor. It will be less expensive and more efficient than a diesel-powered compressor. . . .

We have hired two geologists to begin geologic studies of the property. Much information already exists and is being entered into [a] computer to generate working mine maps. On May 23 an EM-16 survey was conducted. This is an electromagnetic survey using Very Low Frequency (VLF) technology. It may help us delineate rock contacts, fault zones and vein structures. Other plans include underground seismic studies, ground probing radar and extensive structural geology. . . .

We have purchased a semi-trailer to convert into a mobile mine office and equipment storage shed. . . .

An apartment has been leased for the mine crew. Dubbed "The Fairplay Hilton," it will house up to eight people. . . .

Graham Sutton, a Phoenix area mineral miner, has signed on as one of our mine crew. . . . As you know, Bill Kazel is our mine manager and will supervise all mining activity. . . .

***Figure 19.* Graham Sutton working on a new portal, June, 1991. Photo by Bryan Lees.**

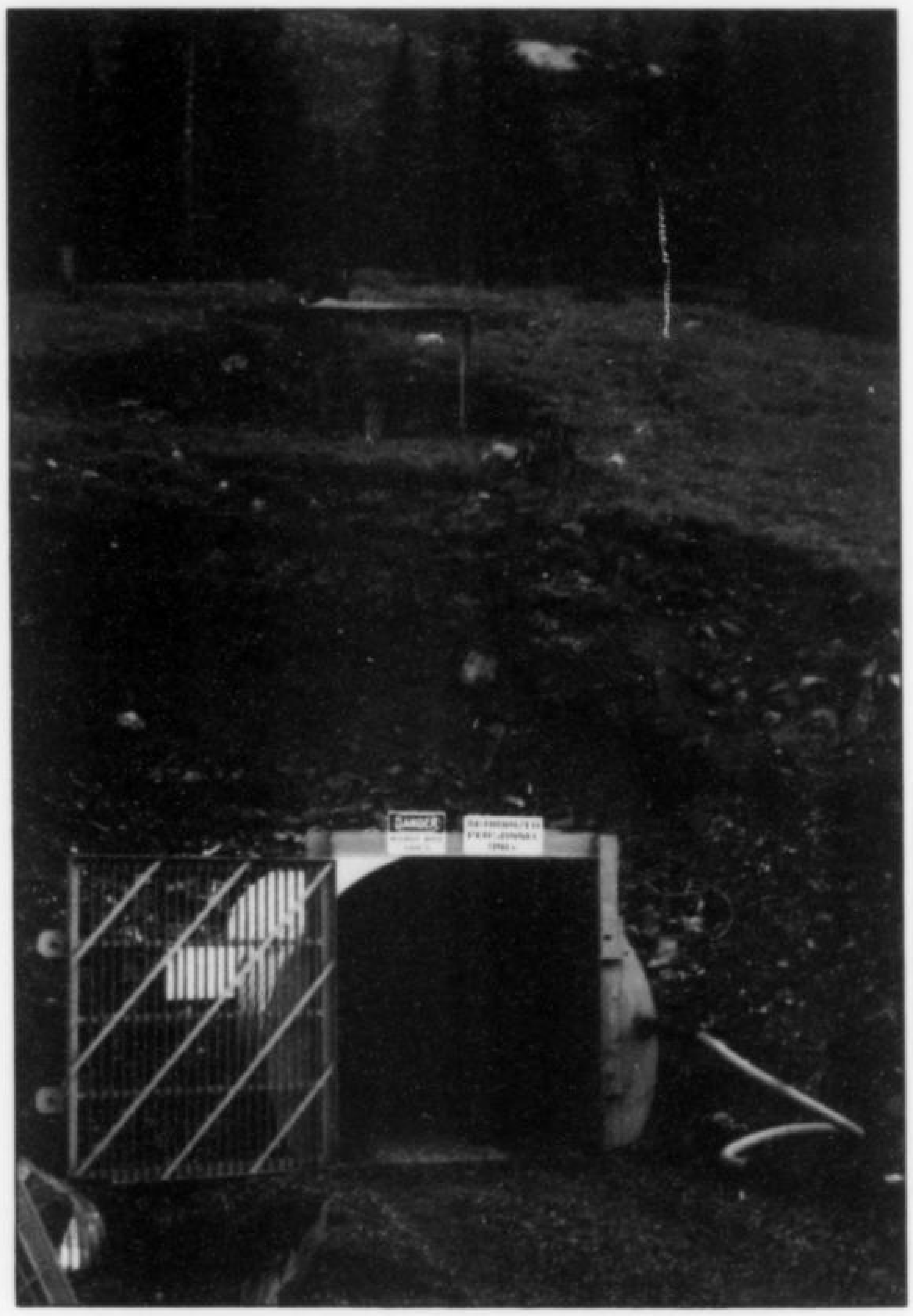


***Figure 20.* New mine portal and ventilation system (above the portal), June 1991. Photo by Bryan Lees.**

Amazingly, the entire project is already under budget due to good planning and a little dumb luck.

As you can see, everything is now in motion. So hang on and enjoy the ride.

Submitted for your approval,
Bryan K. Lees
President and Chief Rumormonger
Sweet Home Rhodo, Inc.

The next bulletin, on July 8, reported much progress particularly on the legal/bureaucratic and mine-engineering fronts. To begin legally operating the mine, Sweet Home Rhodo, Inc. was required by the Mine Safety and Health Administration (MSHA) to have an operating mine safety program encompassing every phase of mine work. All miners had to go through a mine-site training program administered by an MSHA instructor. Further, the mine was required to comply with "the myriad other requirements necessary for legal operation . . . [including] posting of signs, mine maintenance schedules, emergency rescue systems, mine site communications between Sweet Home and someone in Alma and others too numerous to list here." One day, for example, a team from the Colorado Bureau of Mines, whose jurisdiction overlaps that of MSHA, showed up, expressed worry over some apparent radon gas in the mine and reminded the Sweet Home people to have their air compressor inspected (they did, and it passed).

The air compressor, the first of two to be used during the project,

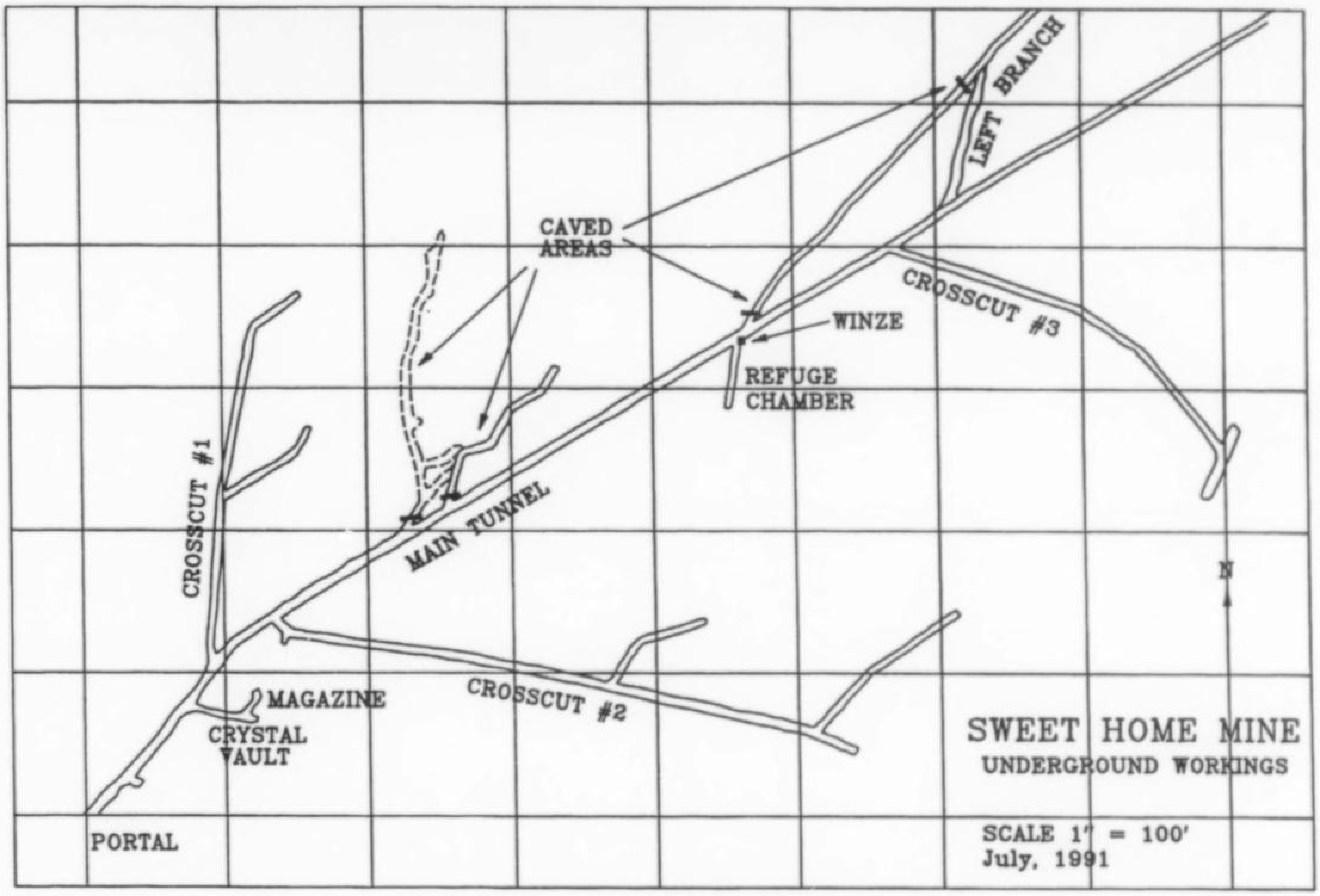


Figure 21. **Extent of the underground mine workings as of July, 1991. Most of these tunnels were made during the 1920's.**

was a used screw-type which Sweet Home Rhodo, Inc. bought for $5500. Electrical service was delivered in early June. And the master engineering feat of this period was successfully performed: the old, rotten wooden portal at the lone mine entrance was replaced by a brand-new 35-foot-long, 8-foot-diameter metal culvert with a secure steel door.

The old rails were ripped up and hauled out of the mine, while a new ventilation system was put in, consisting of a 2-foot-diameter flexible tube to carry air throughout the mine and to channel all radon, carbon monoxide and blast fumes out. A rubber-tired LHD (load-haul-dump) mucking machine was ieased and mine tunnels widened to accommodate this machine, which moves truly dramatic quantities of waste rock from one place to another.

In June, Bryan Lees and Dave Bunk conducted a general underground survey of the mine, finding that the old maps showed most of the tunnels in the wrong places. New survey coordinates were fed into a computer to generate new base maps. Plans at this point were to begin serious specimen mining on July 17—specifically, to work a "secondary" target zone in Crosscut No. 1 while simultaneously widening a tunnel towards the "primary" target in Crosscut No. 3. "The project is proceeding according to plan," concludes this *Sweet Talk*.

By August 6, however, the company was in trouble with an MSHA field agent who had unexpectedly written seven citations against the project, including some on matters that had previously been cleared by the MSHA office in Denver. After several weeks the seven possibly fatal objections were reduced to two. "Compliance with these last two violations is underway," Bryan assured investors, but "[these] MSHA headaches have cost us about 7 lost work days." Roy Rizzardi said:

> I've worked in Colorado mining for 50 years and it's at its lowest point ever right now. And that's not because there's no ore left or because the pay is not still good; it is. But there are too many environmental regulations, too many costs and delays, and a lot of morale is shot. Besides all the hard work.

Now approaching completion was the last major mine rehabilitation task: widening Crosscut No. 3 beyond its intersection with the main tunnel. Thereafter, the company hoped to direct at least 90% of its underground efforts toward specimen exploration. The crew was now working a steady 5-day week, Wednesday through Sunday.

In hindsight, Bryan Lees had a few things to say about this widening of the crosscut:

> The widening [of Crosscut No. 3] required dynamiting about 1 to 2 feet off the tunnel walls. It is called "slabbing." Graham Sutton arbitrarily decided to widen the tunnel on the right side. After one week, about 150 feet of the tunnel was widened and Graham and I were reviewing the latest blast. I was poking around at some pyrite and fluorite exposed by the blast and further down the tunnel Graham was doing the same. Suddenly I heard, "Hey, Bryan, you better come over here." When I got there, Graham was pulling out one of the finest tetrahedrite specimens I have ever seen from Colorado. Looking back into the pocket, I could see several more. In the middle of the pocket was a beautiful 1½-inch rhodochrosite crystal on matrix with a blue ¾-inch fluorite growing on it. This newly found structure was named the Tetrahedrite Structure—the one we followed in 1992 to the Rainbow Pocket. If we had slabbed the left side of the tunnel instead of the right,

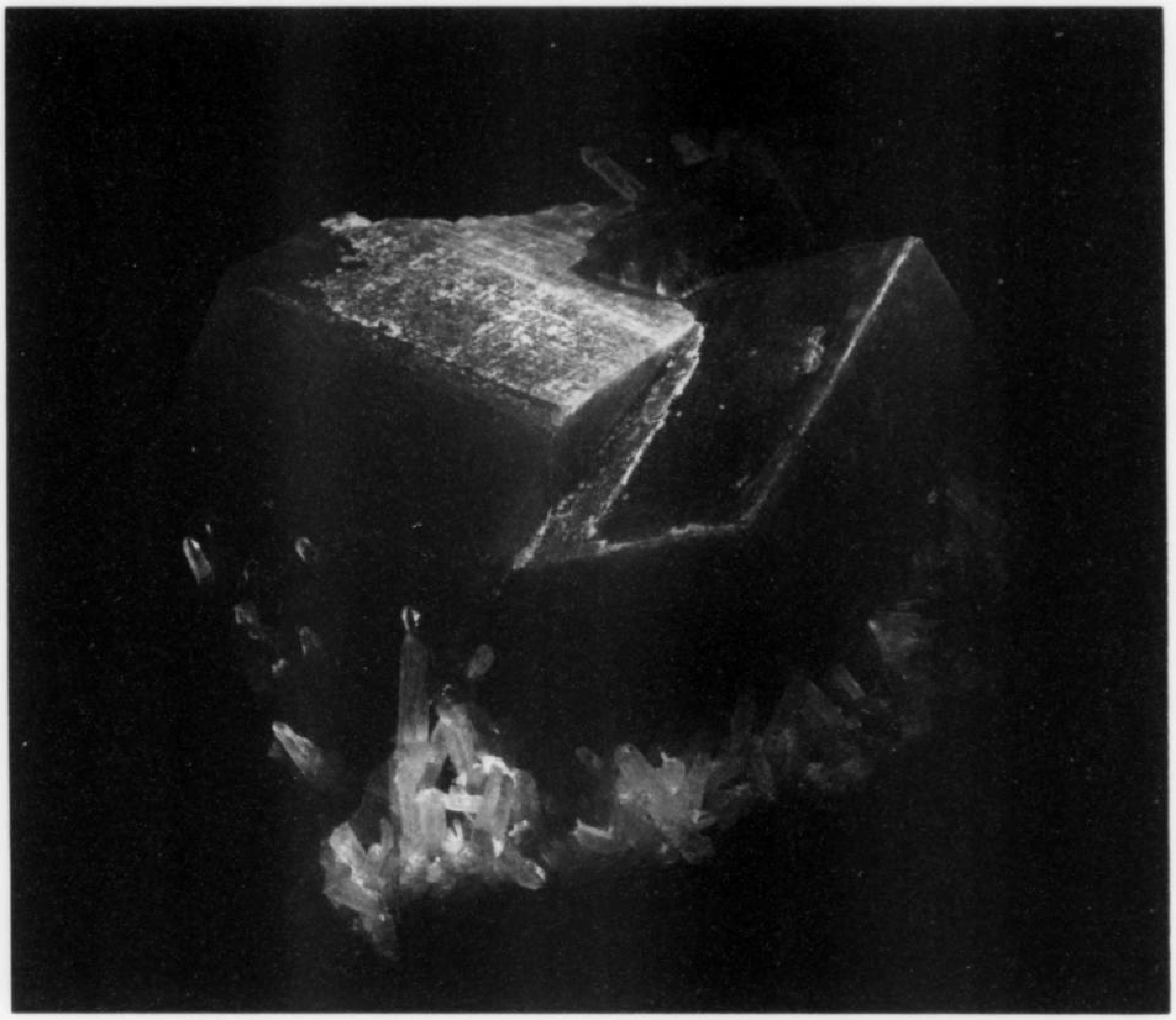


Figure 22. **First fine rhodochrosite specimen discovery, 6.5 cm, with fluorite, from the third crosscut, Sweet Home mine, August 31, 1991. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

would we have missed this structure? If so, we may have had to shut the mine down for lack of funds as early as mid-1992!

The 14 x 25-inch pocket in question here produced an estimated $12,000 in fine tetrahedrite, fluorite and rhodochrosite specimens. On August 31 it was cleaned out in less than three hours. What did the trick was a new mining tool that would subsequently be used to deal with many even greater pockets—the hydraulic splitter. A splitter is a 100-pound, hand-held tool which hydraulically drives a wedge between two "feathers." At the mouth of a pocket just opening up, a series of holes is drilled at regular intervals all around the opening. The end of the splitter is inserted into the holes and expanded slowly to break solid plates off the pocket wall. Performed carefully and correctly, the process is both fast and specimen-friendly, causing minimal damage to crystals and maximizing the production of matrix pieces (e.g., the Alma King).

At this point in *Sweet Talk* we read our first reports of discovered pocket contents. At the end of July, in a target area in Crosscut No. 2, "one nice piece of blue fluorite with small pink rhodochrosites was recovered out of a small 7-inch pocket." The rest of the bulletin concerns similar finds, more tantalizing than truly substantial, although in one place "A very nice rhodochrosite was pulled out after we opened the wall slightly. . . . The specimen has a ¾-inch gemmy red rhomb on clear fluorite and is the best piece we have found."

Figure 23. **Fluorite on bornite-coated tetrahedrite, 5.5 cm, from the Tetrahedrite Pocket, third crosscut, Sweet Home mine, August 1991. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

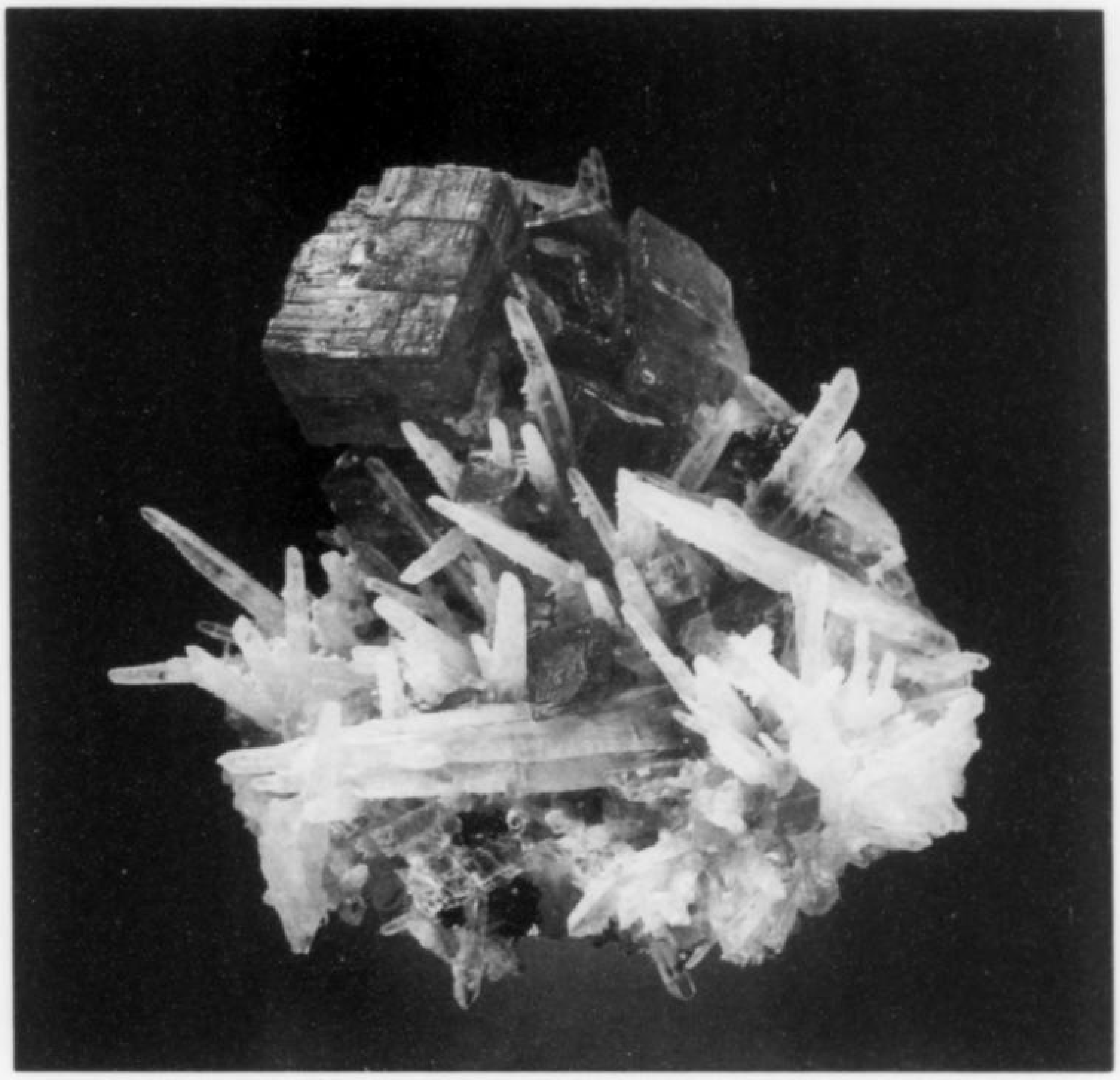


Figure 24. **Rhodochrosite on quartz, 5.1 cm, Watercourse Pocket, third crosscut, Sweet Home mine, September, 1991. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

By *Sweet Talk* number 4 (September 16, 1991), this kind of promising note was being struck much more often. Crosscut No. 3, for example, had by this date produced "about a dozen gemmy, lustrous red rhodochrosites . . . not on matrix and . . . encased in a very fine white china-like clay." Increasingly, good specimens of fluorite, green apatite and tetrahedrite were also encountered: "One tetrahedrite measured 2 inches across and was perched on small quartz crystals. Small ¼-inch gemmy blue fluorite crystals were sprinkled on the tetrahedrite for flavor."

From late August into early September 1991 the crew's main focus was driving a drift along the "watercourse," a vein paralleling the one which in 1966 or 1967 produced the "Bancroft" specimen (see "History: The Sweet Home mine, 1873–1989," this issue). On September 11, a 12-inch pocket here yielded a beautiful 1-inch rhodochrosite rhomb on needle quartz. September 13 saw the debut of contemporary Sweet Home specimens at the Denver Show. *Mineralogical Record* editor Wendell Wilson and Tom Gressman took a break from the show to come up for a mine tour.

In late September, a new geological team began a new month-long survey of the Sweet Home mine. The two principal players on this team were Chuck Turley and Dean Misantoni. According to Bryan Lees:

> When we began the project we didn't have any treasure maps to lead us to the rhodochrosite, neither did we have confidence in which way to go. Underground, our choices were to go upwards, downwards or sideways. To get some advice we enlisted the help of several geologists and mining engineers. Each had a different opinion and some had none at all. Most told us that our targets were too small to predict. It wasn't until Dean Misantoni and Chuck Turley showed up that we began to get a handle on the geology. The mine was mapped in excruciating detail with special attention devoted to structure. By the end of the year, Dean had broken the structural geology problem down into three basic interrelated fault systems and had most of them mapped (see article, "Geology of the Sweet Home," this issue). These interrelations would be studied in detail for the next several years in an effort to model potential target areas. As these models were being worked out, Bill Kazel and the mine crew began probing some of the obvious areas in an effort to begin accumulating empirical data on vein development and to test our geologic theories.

The final *Sweet Talk* told the rather disappointing, although educational, end-of-the-year story:

> In our last update, we were beginning to drift on the watercourse. We thought there was a possible intersection between [it] and the main stope. Unfortunately, the strike of the watercourse changed and began paralleling the main stope so we stopped the drift at 37 feet.
>
> The watercourse drift [vein] was very interesting. It formed along a fault and throughout its length it showed a ½-inch open seam which periodically widened into small pockets of rhodochrosite. One pocket measured 18 inches high and was large enough to insert an arm . . . this pocket was a quartz-lined vug devoid of rhodochrosites. The vug closed off and 6 inches later opened again into a rhodochrosite pocket measuring about 7 inches in diameter. The rhodochrosites were of a curved habit as opposed to the classic sharp rhombs associated with this mine . . . [and] were also slightly etched and quartz-coated, showing evidence of a late silica-bearing stage flooding the entire seam. Without this stage, the rhodochrosites would have been beautiful. The specimens we found had a distinct Sunnyside mine, Silverton, Colorado, appearance.
>
> The watercourse vein took a 40-degree turn into what we now know was a vein flexure. . . . We have now identified several flexures throughout the mine. They sometimes control pocket deposition when pulled apart by reverse faulting.

Thus even in the absence of mega-specimen payoffs, the mine crew was learning much. All hands now knew to regard these vein

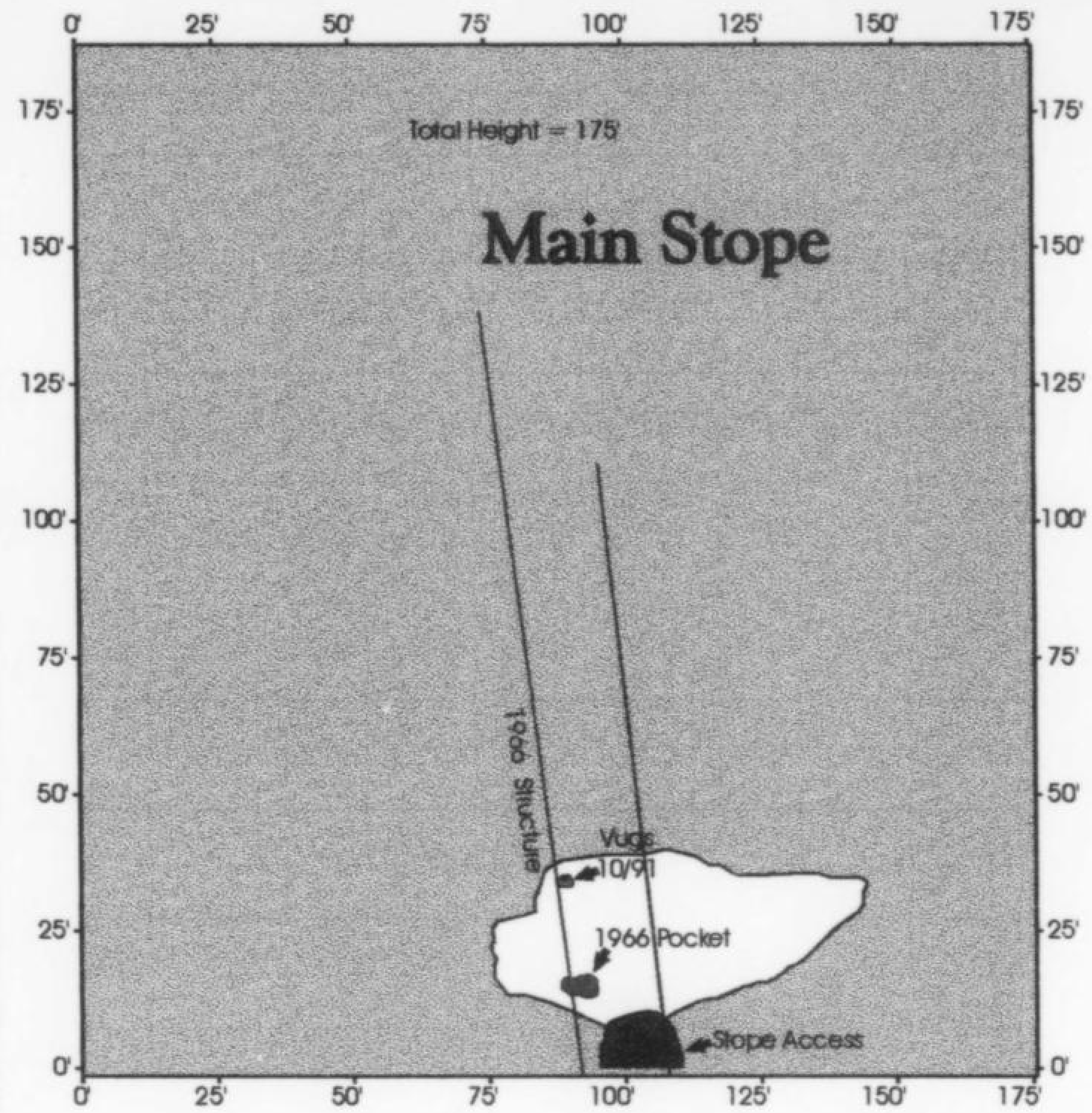


Figure 25. Workings in the Main Stope, third crosscut, as of October, 1991. The stope was worked first in 1966 when the famous "Alma Queen" was discovered (note location on map). Graphics by Bill Tanaka.

flexures as hints of pockets ahead, especially in the presence of other related deformational features. Also, the "late silica-bearing stage" was already coming to be a familiar killjoy. Many a later pocket would produce rhombs whose aesthetics would be more or less ruined by the thin, opaque, secondary coatings of silica and low-grade rhodochrosite.

Meanwhile a manufacturer's demonstration of a rock-cutting ring saw was resulting in mixed reviews. And Sweet Home Rhodo, Inc. was becoming enamored of a "borehole scope"—literally a medical endoscope—that could see directly into vugs 6 feet down a drill hole, reducing the risk of destroying a good pocket by blasting too close to it. "The cost of the unit is $10,000. We are looking for a used one," *Sweet Talk* owns up ruefully.

Readers were apprised of progress in the ongoing geological, geophysical, geochemical and petrographic studies being conducted by the Lees/Turley/Misantoni team with some outside help. Structural data from the surface and underground surveys, now completed, were in the process of being turned into both two and three-dimensional mine maps. Russ Honea, a mineralogist and petrographer, was doing polished and thin-section studies of the various rock units in the mine. And the geochemical work then in progress promised to furnish a better understanding of the relationship between vein structures and mineralogical characteristics: "For instance, some veins would exhibit sulfide-group mineralization while others showed only quartz and pyrite. Both veins would have rhodochrosite in them. A big question is, which sort of vein we should mine on." In a kind of early rehearsal for later, more thorough work, Sweet Home Rhodo, Inc. looked at elements (like iron, strontium and magnesium) which can substitute for Mn in rhodochrosite. Crushed samples from every known rhodochrosite-bearing seam were analyzed by atomic absorption spectrometry in order to correlate the abundances of the trace elements with the known distribution of "good" pockets. Unfortunately, this early geochemical work did not produce usable results. However, it did assure investors that no trick of modern geological science would be neglected in the attempt to "mine smart."

Methods had meanwhile been devised for timbering the main stope and for working in raises: "The top platform is removed each time before a blast so that it is not destroyed. . . . This method allows us to get right up to the face for cleaning and collecting vugs." Also, the plan to backfill the mine to dispose of as much muck as possible was going well, except that the tunnels were filling up faster than anticipated.

Personnel change: miner Graham Sutton left for Arizona and his replacement, Rory MacDonald, was hired. Rory, most recently of the South London mine, brought with him a reputation as one of the best hardrock miners in the area.

Perhaps most importantly for the future, *Sweet Talk* readers were told, Sweet Home Rhodo, Inc. settled at last on an optimum method for placing blast shots while also probing for pockets. The earlier-practiced technique of blasting parallel to the vein structure and then going back and peeling the wall to expose pockets had been too slow and not cost effective. So they began drilling straight back into veins in the regular course of putting in blast rounds and waiting to feel the drill leap forward should it breach a pocket. On October 31, while drilling in this way, the miners broke into two 7 x 12-inch pockets that yielded some outstanding small rhodochrosite specimens and "the best piece of cutting rough [Bryan had] ever seen." Combined with the promise of the borehole scope and the already proven efficacy of the hydraulic splitter, this drilling-into-the-vein strategy now seemed to give the Sweet Homers the way to find more pockets large and small, to minimize

***Figure 26.* Beautiful, perfect rhodochrosite crystal from a small, unnamed pocket is held by Rory MacDonald, October, 1991. Photo by Bryan Lees.**

damage to them and to take out lots of matrix specimens, all while moving as little waste rock as possible.

At the very end of the 1991 season (as if the mine had deigned to serve up a nice dessert), Bryan Lees reported that:

> Rory, Greg and I were finally putting the first blast rounds into the Main Stope, [and] we hit a small 8 x 8 x 1-inch clay-filled pocket about 20 feet above the great 1966 find. I slowly washed the clay out of the pocket and, to our amazement, exposed the best rhodochrosite of the season—a perfect floater 1-inch rhomb. It was so clear that you could read newsprint through the double refraction (Fig. 26).

On October 16, mining ceased for the 1991 season. Chief among the corporation's winter tasks, besides the work on the science, was raising money. Encouragingly, the sale of specimens was already beginning to help. All told, about $50,000 worth of specimens were dug in this first year. It was not yet the blockbuster story it would become in the 1992 season, but the Sweet Home project was, unmistakably, healthy and growing. It would be preparing, all that winter, for its passage into the exhilaration of the 1992 season.

THE 1992 SEASON

The major source used for information on the events of this season and of the '93 and '94 seasons is the personal mining journal kept by Bryan Lees. Unfortunately, this account cannot reproduce the journal's sketches of pockets, specimens, geological structures and mining techniques. And because much of the work of mining is routine and dull, the language here is paraphrased and telescoped, except for some passages on "peak" events, where direct quotation is used.

The general approach was to work in each of two distinct areas of the mine. In '92 and '93, the two major working areas were called the "Main Stope" and the "Tetrahedrite Drift," and the most exciting action was sometimes in one, sometimes in the other. Miner Rory MacDonald was responsible for work in the "Main Stope" while Scott Betz concentrated his efforts in the "Tetrahedrite Drift."

Here, then, is the most frenzied part of that ride that Bryan had promised his investors the year before. . . .

June 6: They resume blasting on the old watercourse vein. A 14-inch pocket yields opaque rhombs of rhodochrosite on needle quartz.

June 12: In the Main Stope, they hit a 6-foot diameter pocket with no rhodochrosite but good ¼-inch fluorites on quartz and sulfides.

June 13: In the Main Stope, they set off a shot at the end of a shift. The next morning they find the contents of a small pocket, 1-inch rhodochrosites and 1-inch fluorite dodecahedrons, lying on the muck pile.

June 14–18: Two pockets in the Main Stope are opened—one empty, one with cutting-grade rhodochrosites broken in the blast.

June 19–20: What seemed at first a 3-foot pocket in the Main Stope turns out to be two 1-foot pockets with 100 mediocre rhodochrosites and associated species.

June 21: A blast to square up the working face reveals a pocket with one gemmy 2 x 3-inch rhodochrosite cluster.

June 26: In the Main Stope, they set off a shot and move 12 inches further into the working face, revealing a pocket with abundant but heavily damaged rhodochrosites. A 1 x 4 x 6-inch crystal sandwiched in the vein is pulled out in ten pieces. There are promising hints of further pockets and rhodochrosite showings. They can hear water percolating back in the vein and see a trickle coming out of a drill hole.

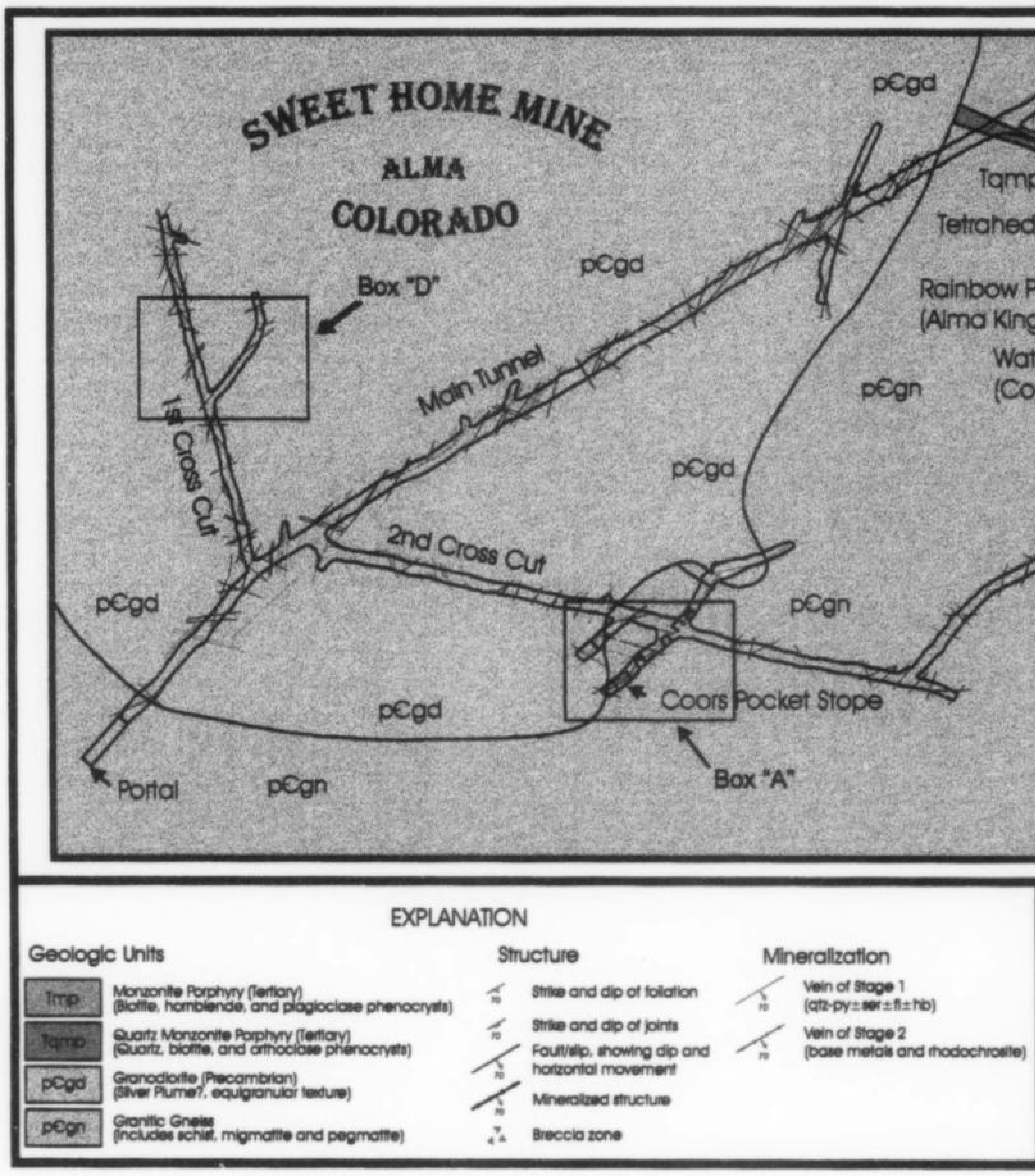


Figure 27. **Simplified geologic map of the Sweet Home mine showing lithology, structure and mineralization. Geology mapped by Dean M. Misantoni; graphics by Gene Kooper and Bill Tanaka. Details of Box "B" and "C" are shown in Figures 28 and 33.**

July 4–5: A 6 x 6-foot, 2½-inch-wide pocket in the Main Stope is opened—nothing inside. Meanwhile, a new pocket in the Watercourse Vein produces a 1½-inch rhodochrosite on needle quartz and some fine pyrite miniatures. On the working face, another pocket comes up empty but for some "crummy fluorites."

July 6 [Discovery of the Cash Flow Pocket]: Rory shoots on both sides of a quartz/sulfide lens on the ceiling of the Main Stope. On one side is a rhodochrosite-filled breccia vug 5 feet wide looking like a major find. Bryan Lees:

> Within a month [of beginning the season] we had not discovered anything important in what we considered to be the best area of the mine, the Main Stope. We had also spent ⅓ of our remaining money and I was getting worried. Fortunately, by July 6, we finally had a bit of luck. . . .

July 10: Bryan begins investigation of the Cash Flow Pocket. He pulls out 10-inch matrix plates with quartz crystals and ¼ to ½-inch rhodochrosite rhombs, silica-coated. Off to the left of the pocket, another one opens out with hundreds more silica-coated rhombs. Bryan Lees:

> Although the specimens were not the top material we hoped to find, all I could think of as we removed the contents was that we would finally have some cash flow (and thus the name of the pocket) from all our efforts.

Meanwhile, work on the Tetrahedrite Drift by Scott Betz takes up where it left off in the '91 season. A pocket in massive tetrahedrite produces a 1½-inch rhodochrosite rhomb with blue fluorite.

July 11: While Bryan returns to the Cash Flow Pocket in the Main Stope, he turns Rory and Scott loose on "their first important vug" in the Tetrahedrite Drift. They extract a magnificent 4-inch specimen. Jack Murphy from the Denver Museum of Natural History shows up to photograph the Cash Flow Pocket. Bryan's hands now "look like hamburger meat from quartz-lined vugs."

July 12: More blasting in the Tetrahedrite Drift. One pocket yields six very good tetrahedrite specimens and about 50 lesser ones. Another pocket, just showing, awaits investigation the next day. This will turn out to be the Colorado Springs Pocket.

July 13: It appears that the Colorado Springs Pocket collapsed long ago; large rhombs are lying loose in it, many etched by later solutions percolating through. The walls show traces of 7-inch crystals. Loose, etched crystals "look almost like red sugar-coated gum drops." There turn out to be 100 pieces in all. Bill and Carol Smith come up to see the pocket.

July 17: A big day in the Tetrahedrite Drift. A new vug produces some beautiful chalcopyrite-coated tetrahedrites that look like old Cornwall specimens, and about 90 rhodochrosites, including a 1½ x 1½ x 1½-inch rhomb on quartz and a 1½ x 1½ x 1½-inch killer.

July 24: While Cash Flow Pocket work continues, some more good pieces with 2 x 4-inch rhodochrosite on well-crystallized tetrahedrite come from the Tetrahedrite Drift. And here a new, 4 x 2-foot pocket is breached—the Museum Pocket.

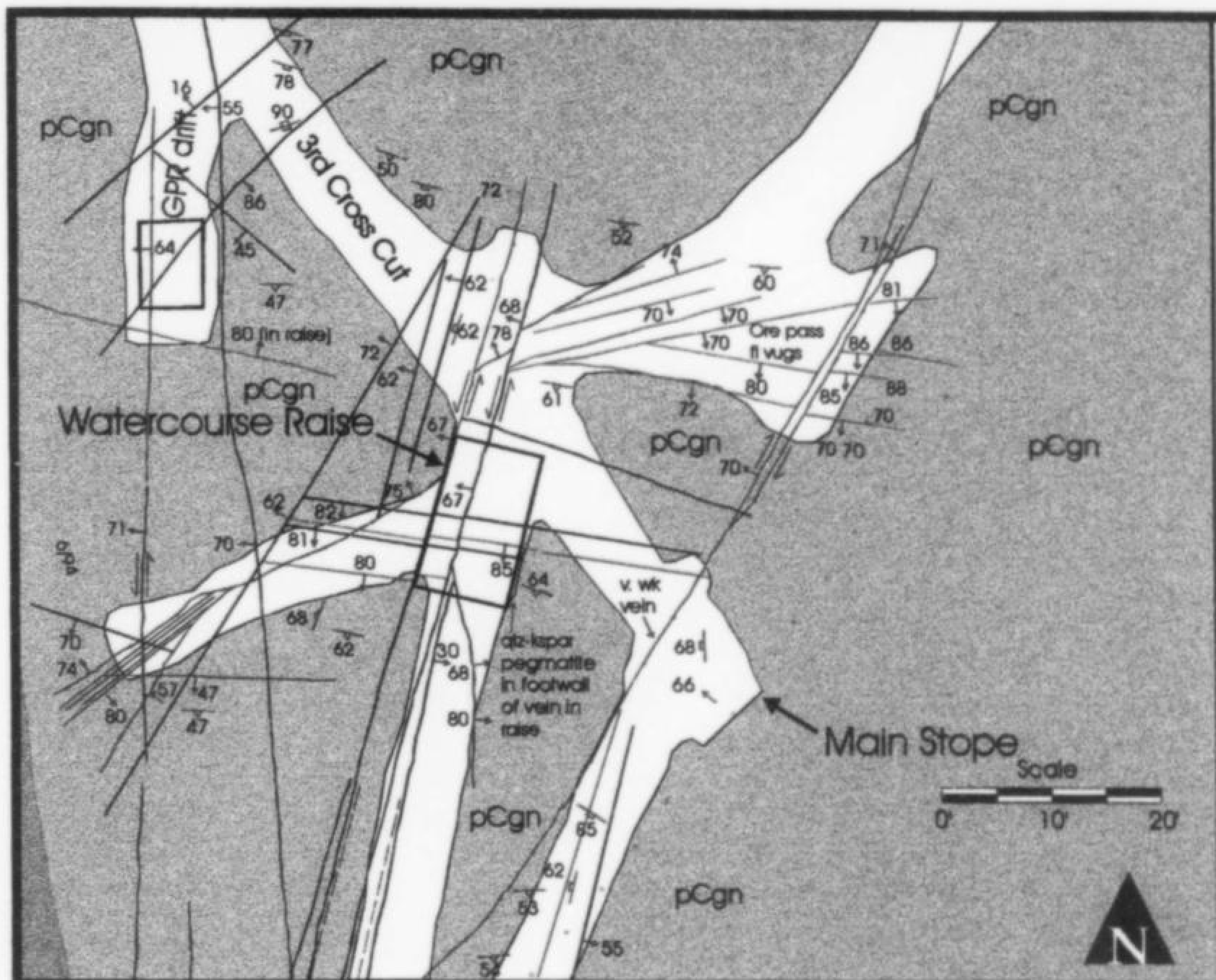


Figure 28. **Detailed geologic map of the Main Stope and Watercourse Raise areas, showing lithology, structure and mineralization. The area shown corresponds to Box "B" on Figure 27. Graphics by Bill Tanaka.**

SWEET HOME MINE
ALMA
COLORADO

BOX "B"

EXPLANATION

Geologic Units

- Tmp — Monzonite Porphyry (Tertiary) (Biotite, hornblende, and plagioclase phenocrysts)
- Tqmp — Quartz Monzonite Porphyry (Tertiary) (Quartz, biotite, and orthoclase phenocrysts)
- pCgd — Granodiorite (Precambrian) (Silver Plume?, equigranular texture)
- pCgn — Granitic Gneiss (Includes schist, migmatite and pegmatite)

Structure

- Strike and dip of foliation
- Strike and dip of joints
- Fault/slip, showing dip and horizontal movement
- Mineralized structure
- Breccia zone

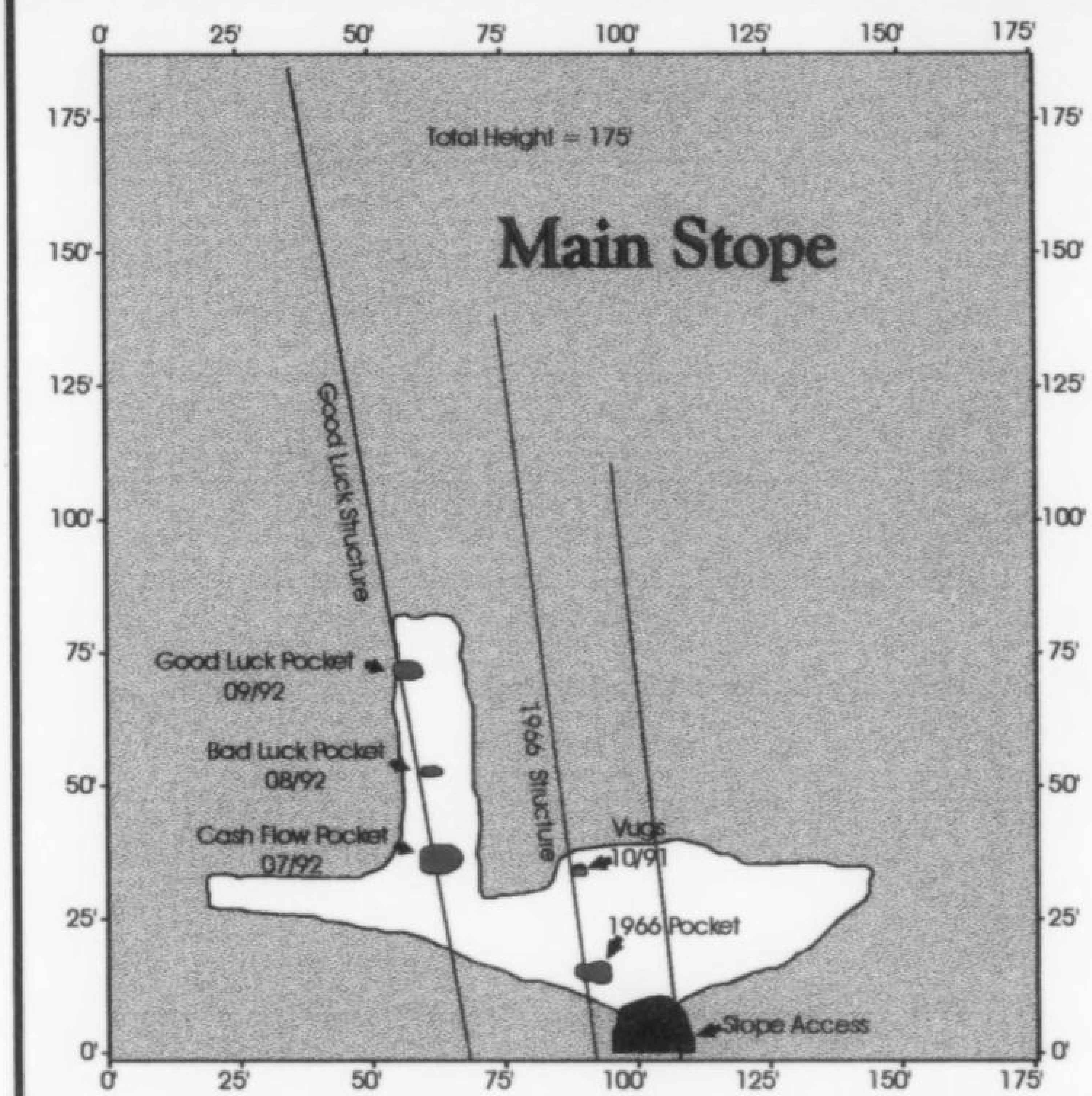
Mineralization

- Vein of Stage 1 (qtz-py±ser±fl±hb)
- Vein of Stage 2 (base metals and rhodochrosite)

Geology mapped by Dean M. Misantoni
Last revised - December, 1994

Map preparation by C. Eugene Kooper
Last updated - September 10, 1995

Figure 29. **Scott Betz, drills in the Watercourse Vein. Photo by Bryan Lees.**



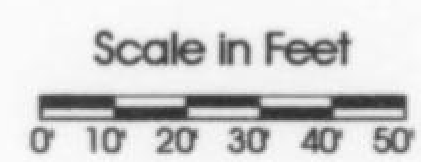


Figure 30. **Section of the Main Stope looking east, 1992. Graphics by Bryan Lees and Bill Tanaka.**

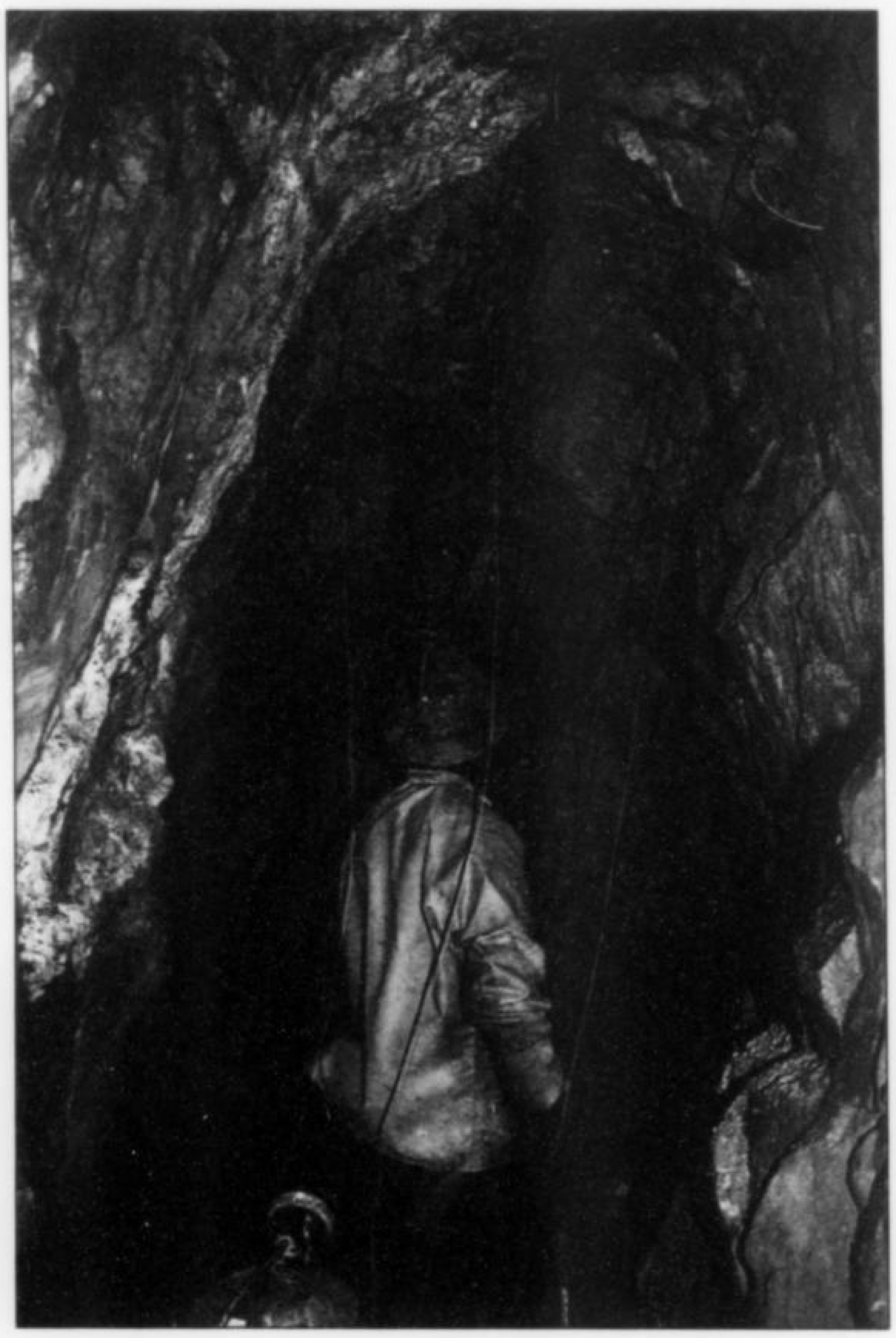
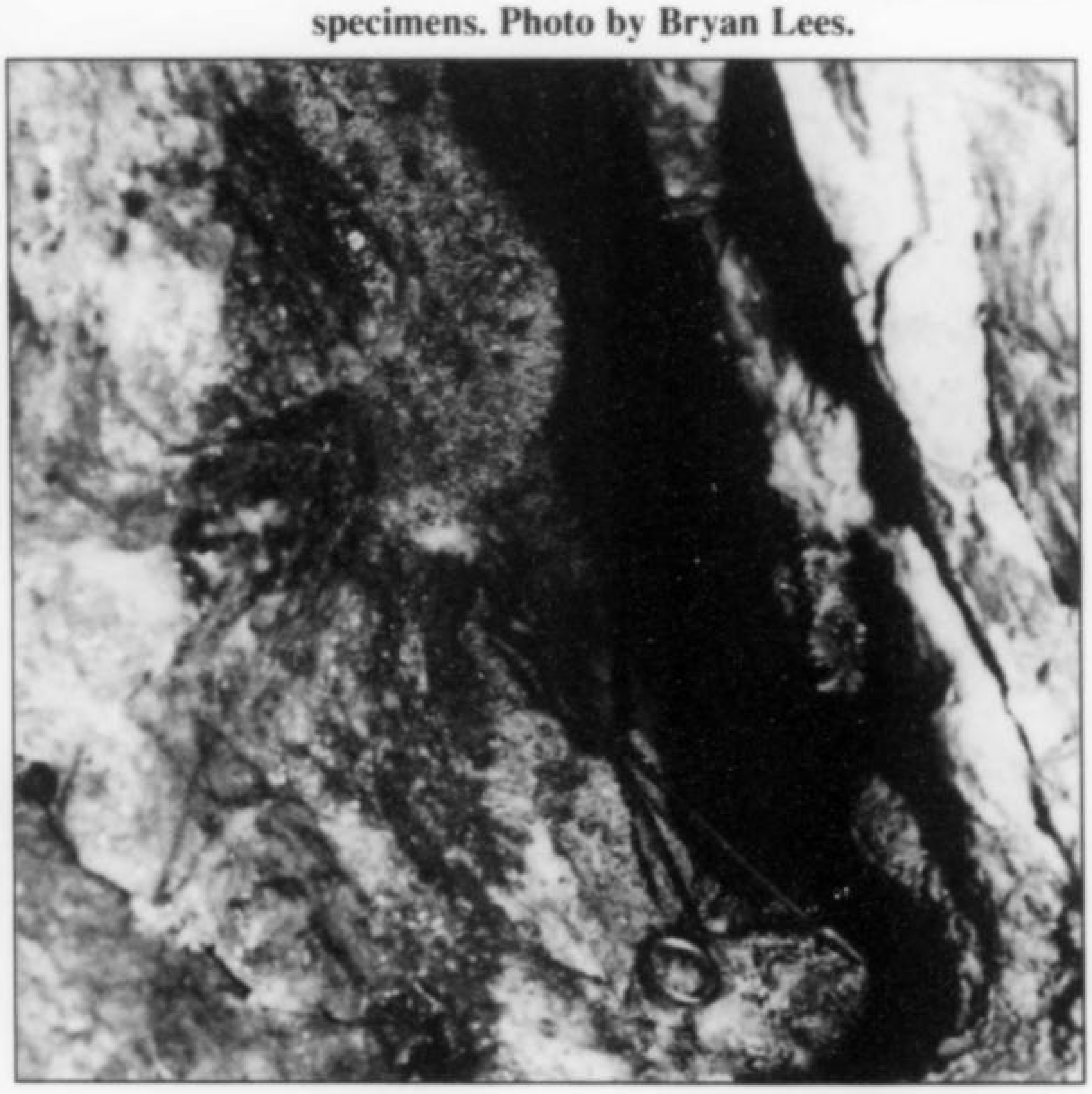


Figure 31. **Rory MacDonald loads dynamite for a "raise round" in the Main Stope. A "raise" is a shaft driven upward and a "round" is a blast which propagates the raise upward 5 or 6 feet. Photo by Bryan Lees.**

Figure 32. **Cash Flow Pocket opens up to almost 6 inches wide and eventually extends inwards 5 feet and upwards 4 feet. Pocket contains hundreds of matrix rhodochrosite specimens. Photo by Bryan Lees.**



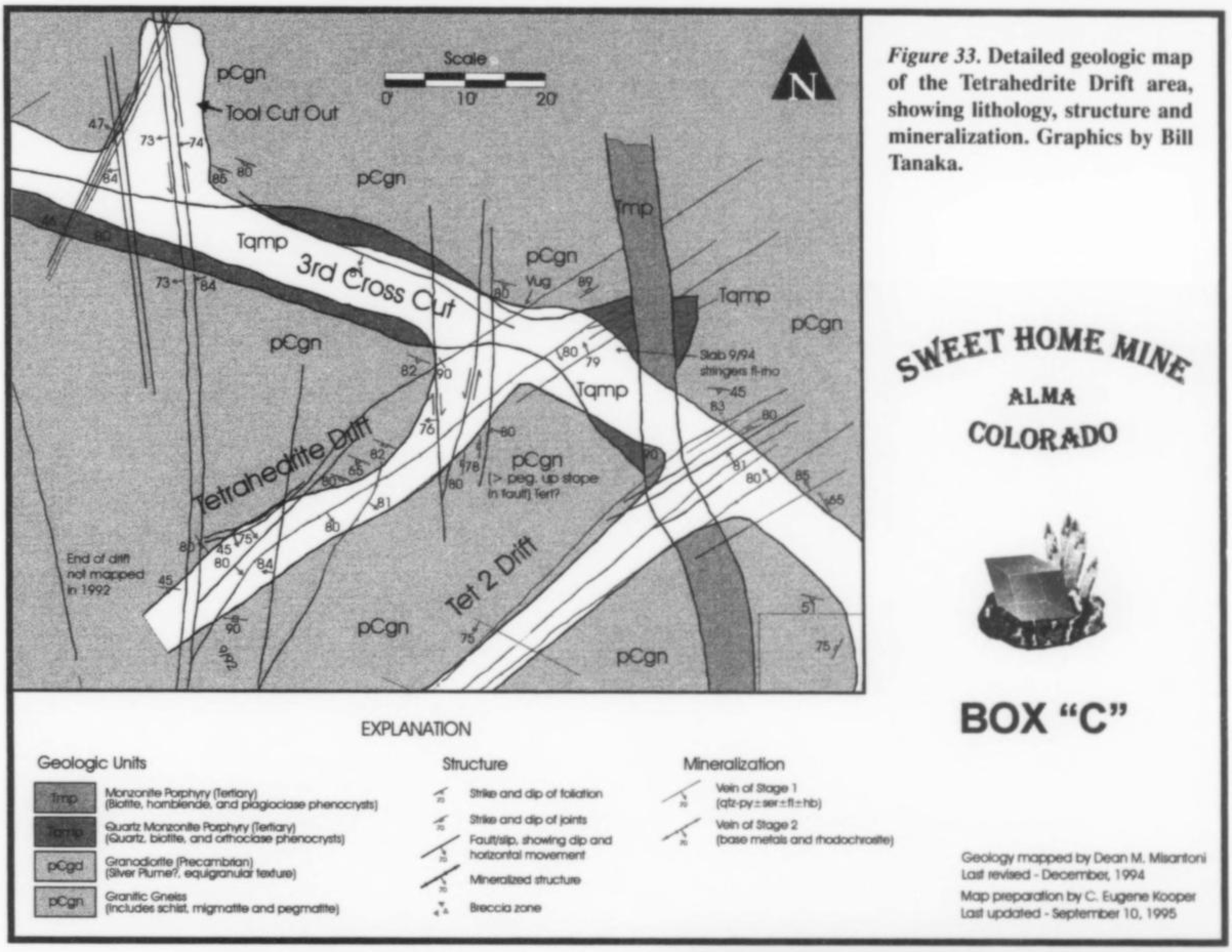


Figure 33. **Detailed geologic map of the Tetrahedrite Drift area, showing lithology, structure and mineralization. Graphics by Bill Tanaka.**

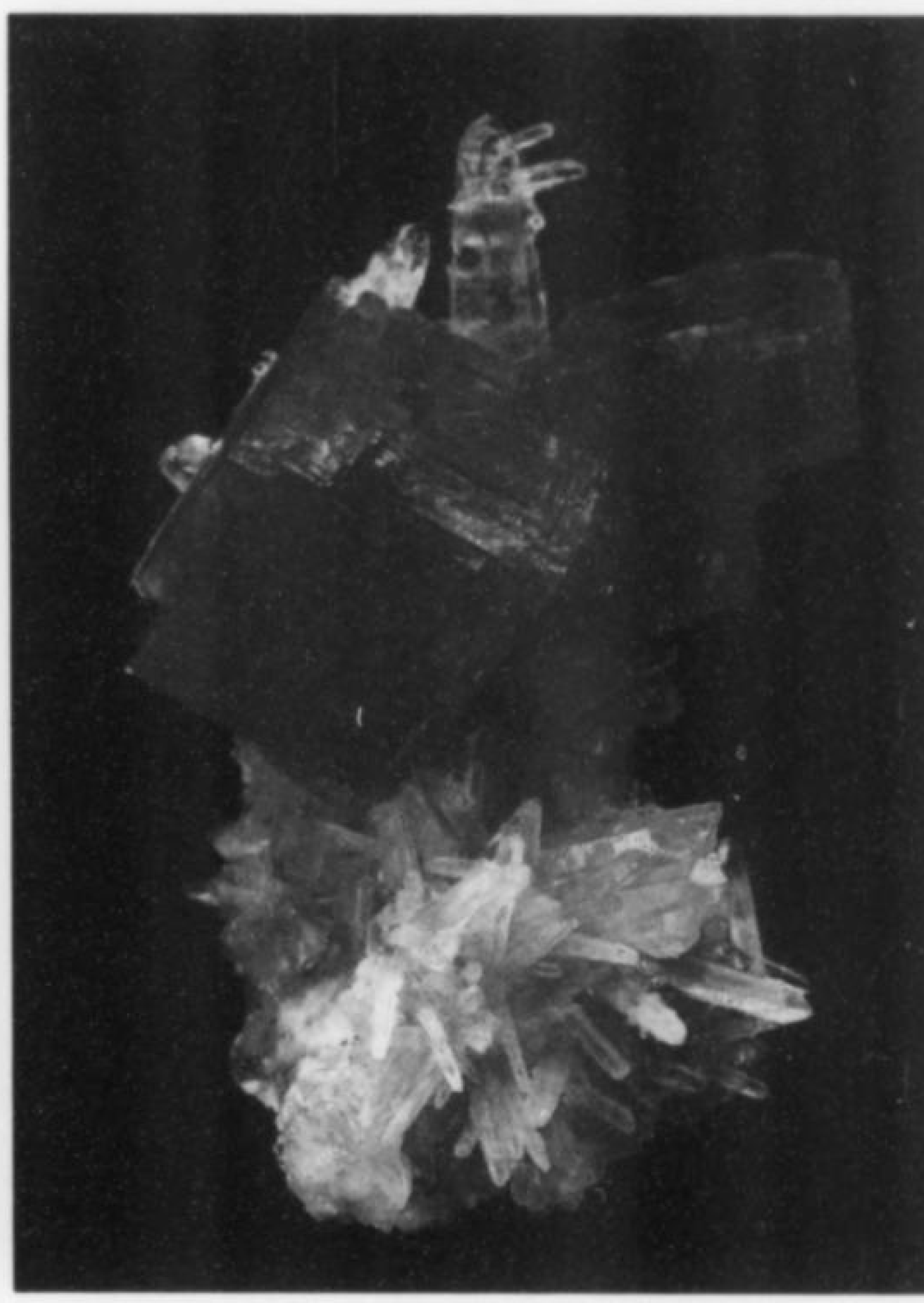
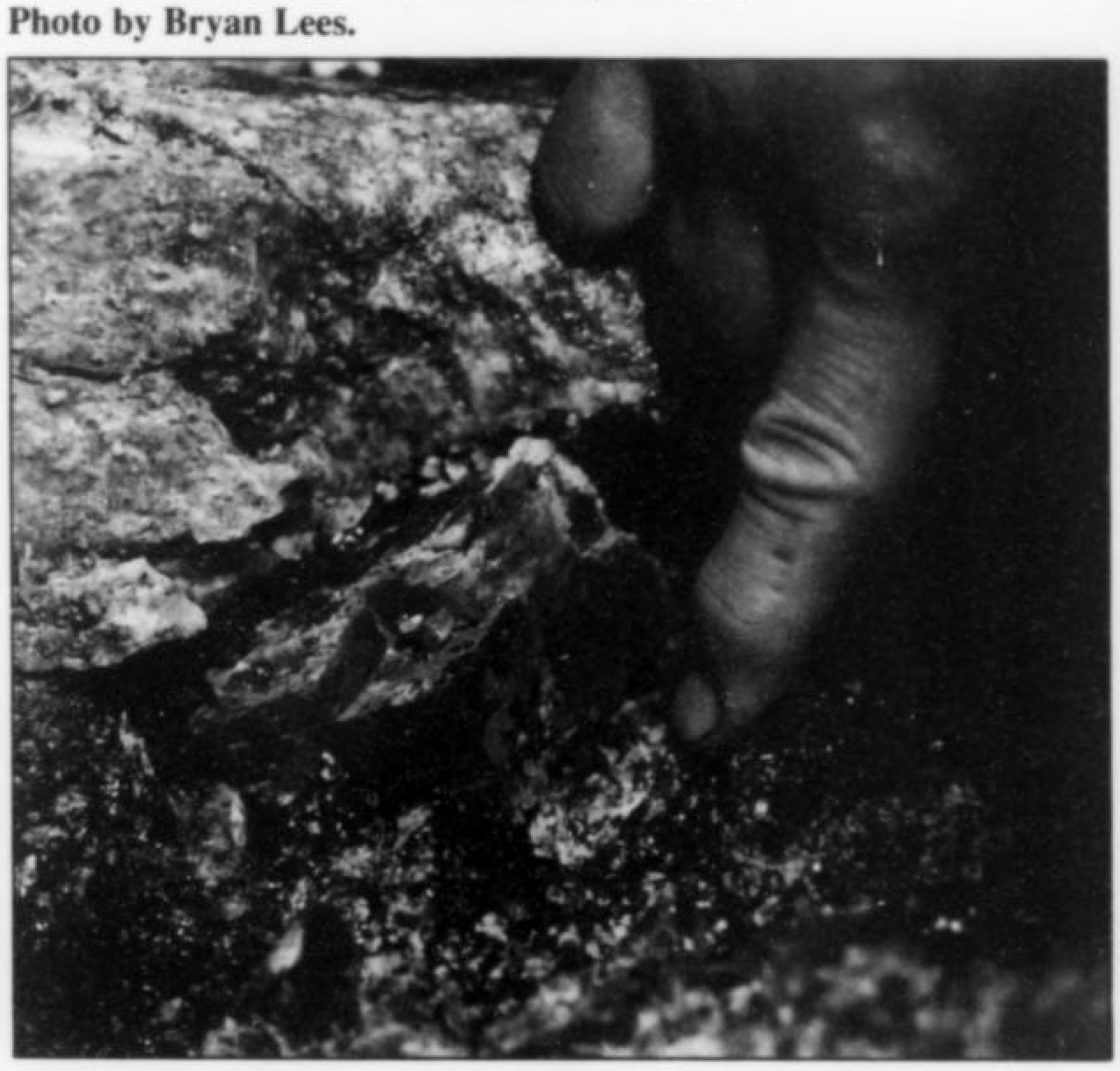


Figure 35. **Rhodochrosite on quartz, Cash Flow Pocket, Main Stope, 4.4 cm high. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

Figure 34. **Rhodochrosite, 10 cm, tucked wall-to-wall inside the Colorado Springs Pocket. Photo by Bryan Lees.**



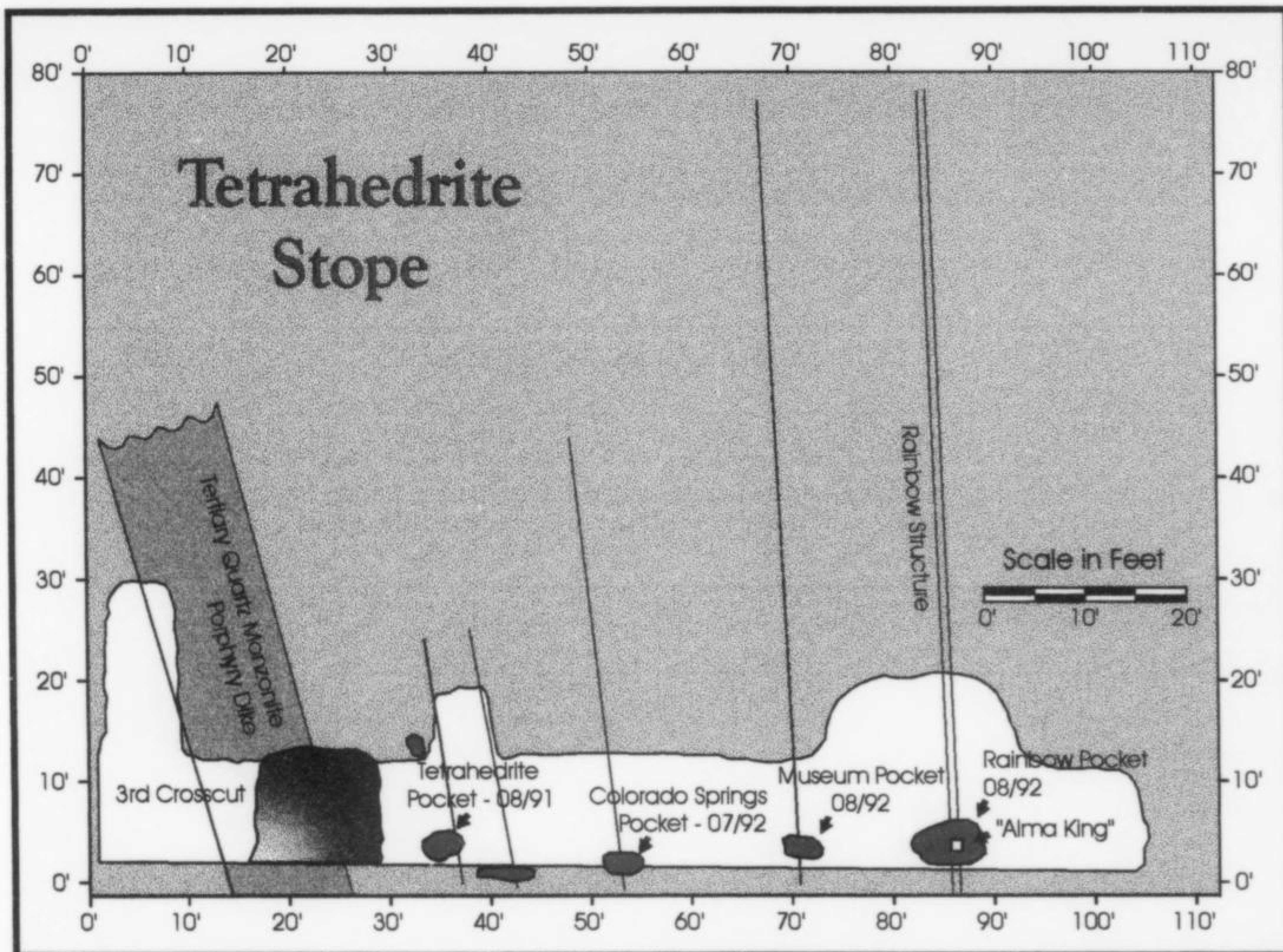


Figure 36. **Section of the tetrahedrite stope in 1992, looking east.**

SWEET HOME MINE
ALMA
COLORADO

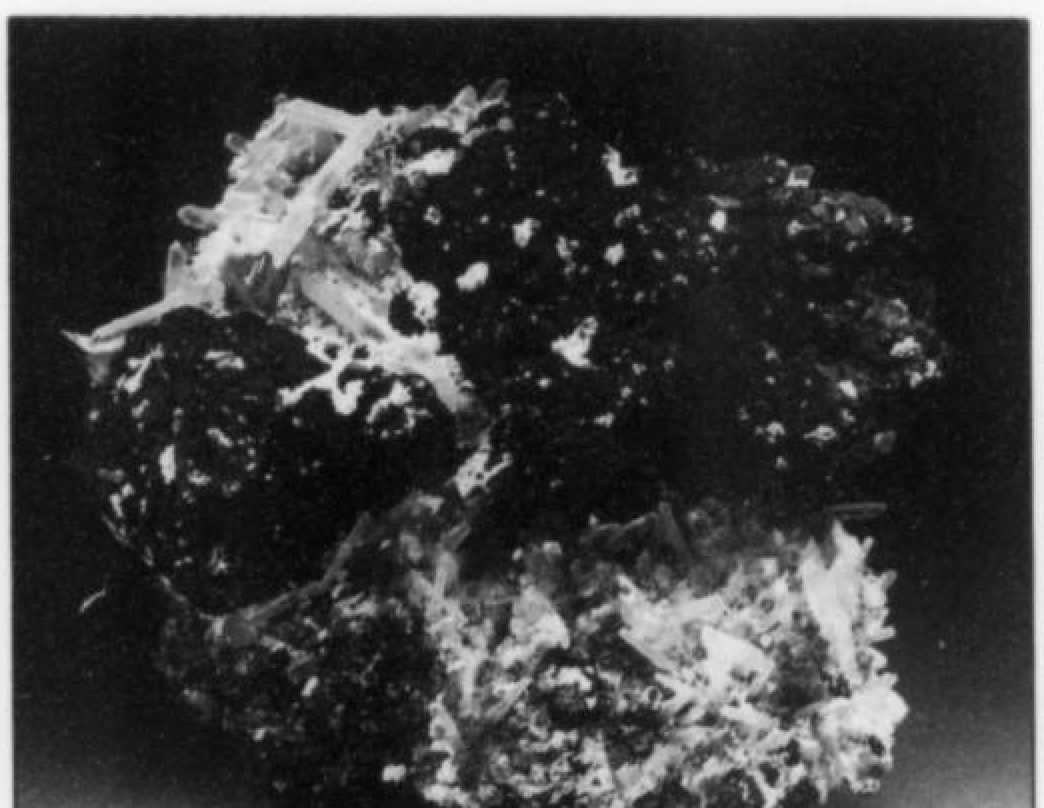


Figure 37. **Bornite-coated tetrahedrite on quartz, 9 cm, Colorado Springs Pocket. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

Figure 38. **Dave Bunk cleans the largest specimen from the Cash Flow Pocket (called "Baby Huey") at the Collector's Edge in Golden, Colorado. Photo by Bryan Lees.**

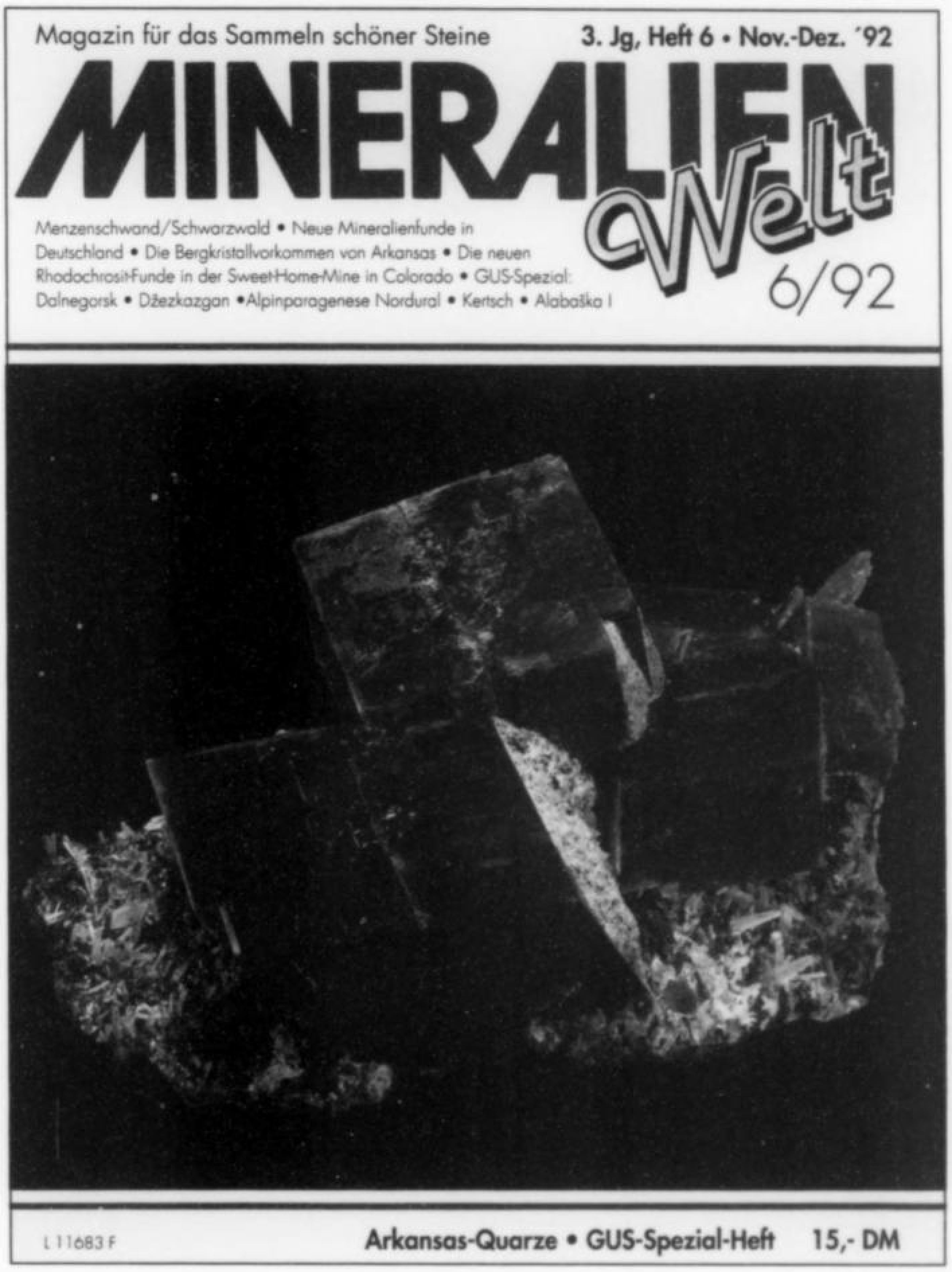


***Figure 39.* The best rhodochrosite from the Museum Pocket after its removal and repair, featured on the cover of *Mineralien Welt* in 1992. Each crystal measures 10 cm on an edge and represents one of the finest specimens ever discovered at the mine. James Horner specimen; photo by Jeff Scovil.**

Bryan Lees:

> Throughout 1992, Rory was in charge of stoping upwards in the Main Stope and Scott was in charge of drifting along the Tetrahedrite Vein. During the month of July, Scott and Rory kept drilling into small pockets that had to be carefully inspected. We discovered four and we had our hands full keeping up with the pocket extractions. We were perfecting techniques to extract the fragile rhodochrosites and, as the summer proceeded, confidence grew that we could save just about anything. One of the four pockets was the Museum Pocket. . . .

July 25: In the Tetrahedrite Drift, the best tetrahedrites yet found: big plates with 1½-inch lustrous crystals, come from the Museum Pocket. Also, several excellent single rhodochrosite crystals are extracted.

July 27: The Cash Flow Pocket is, at last, fully cleaned out.

July 31: In the Main Stope, a small void is discovered beyond the Cash Flow Pocket. At the Museum Pocket (Tetrahedrite Drift), Jack Murphy leads a Denver Museum camera crew to videotape the extraction of large rhodochrosite plates. One 6 x 10-inch plate has a 2-inch and a 3-inch rhomb still on it and shows places where rhombs collected on July 25 (now back at the shop) can be reattached.

Bryan Lees:

> This was the great specimen showcased at the Denver Show in September 1992 and featured on the cover of the German mineral publication *Mineralien Welt*, vol. 3, no. 6, Nov.–Dec. 1992. It contained 3-inch rhodochrosites on matrix with several clear quartz crystals to 2-1/2 inches long. . . . It took us two weeks to extract and Bill Hawes two months to trim and prepare.

August 1: Forty members of the Colorado Springs Mineralogical Society arrive for a tour. In the Main Stope, Rory builds scaffolding to split into the new pocket found behind the site of the Cash Flow Pocket. He has a small accident and severely bruises his ribs. The next day the splitter breaks. The next few days are marked by more minor injuries and equipment failures.

August 6: The splitter comes back, but has been repaired with the wrong parts and is still dysfunctional. In the Main Stope, an attempted shot near the new pocket goes wrong and destroys the entire pocket contents. It is dubbed the Bad Luck Pocket.

August 8: In the Main Stope, the re-repaired splitter breaks down again. . . . But from the remnants of the Bad Luck Pocket, some good thumbnail and miniature rhodochrosites appear—very red with good pyrite, sphalerite and tetrahedrite crystals.

August 9: In the Tetrahedrite Drift, a shot exposes the beginning of a 4 to 5-inch wide vug going straight back into the working face. Promising . . .

August 16–17: In the Tetrahedrite Drift, a pocket is split into—"another etched nightmare." Very red, gemmy rhodochrosite rhombs to 2½ inches but heavily etched. Most rhodochrosites are coated with pale blue, ⅛ to ¼-inch fluorites, also etched.

August 20: In the Tetrahedrite Drift, they finish cleaning out the etched pocket.

August 21 [Discovery of the Rainbow Pocket]: Bryan Lees:

> Near the end of August the company was again running out of money and we were frantic to find something to persuade the investors to keep the mine open. As we discovered the Rainbow Pocket, I was worrying about how we were going to make paychecks at the end of the month. We were that close to going out of business. After the discovery, we were able to borrow enough money to get through the Denver Show and sell the new material. We never looked back.

In mid-afternoon in the Tetrahedrite Drift, they set off a large shot. While the miners are waiting for the smoke to clear, a camera crew from the Denver Museum shows up to see whether there's anything that would be good to catch on film [!]. At the blast site, a 14-inch hole is visible halfway up the working face. When debris is cleared away, a cavity 5 feet deep and 2 to 6 inches wide shows along a left-bending vein flexure. In the darkness, several very large rhodochrosite rhombs, one of them over 5 inches on edge, are spotted lying loose. As the Museum's cameras roll, Bryan pulls out the 5-inch rhomb from its narrow space. It has separated from the hanging wall. [This is the large crystal later re-attached to the Alma King matrix plate.] All present are already going crazy. Bryan's journal says:

> After removing this piece, one could see into the vug further. WHAT A SIGHT! All I could say was "Oh my God, oh my God, oh my God." Because everyone who looked into the pocket said more or less the same thing, we considered naming it the Omigod Pocket. Thought better of it later, though.

Rhodochrosites are everywhere in the pocket. One 4-inch rhomb lies directly on top of another. In the center-back of the pocket, another 5-inch rhomb forms a cluster with some 2-inch and 3-inch crystals. At the top, a beautiful 2½-inch rhomb grows downward from the wall. Many, many ½-inch to 1½-inch crystals are scattered about. Many of these sharp rhombs are coated with blue fluorite crystals to ¼-inch, which also coat both hanging and foot walls. There is a "sugar coating" of light yellow calcite crystals on many rhodochrosite crystal faces. Some rhodochrosites, especially near the bottom, are lightly etched. Bryan Lees:

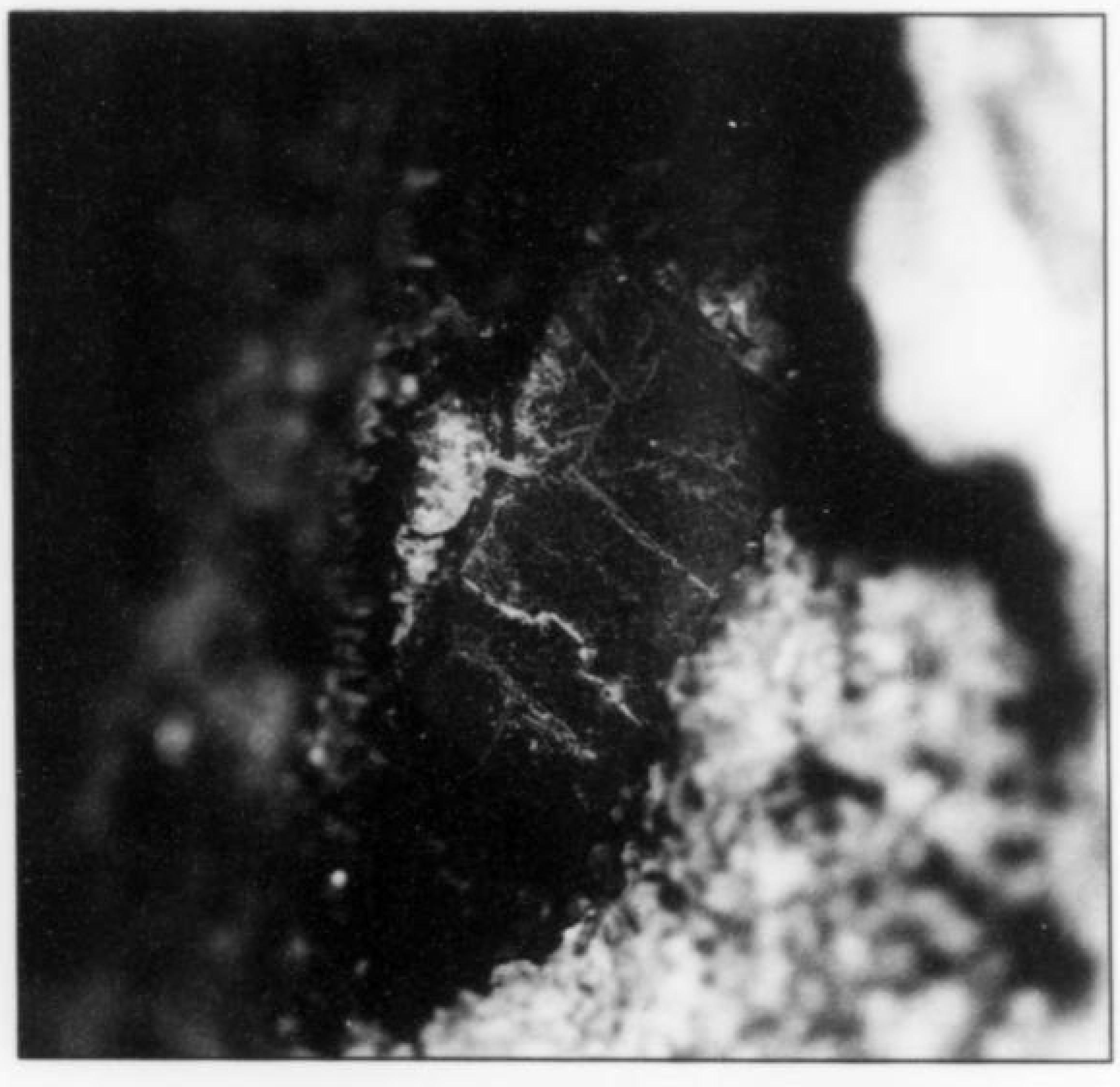


Figure 40. **The "Alma King" crystal lying loose inside the Rainbow Pocket. Note that the crystal barely had room to grow; it is touching both sides of the vug. The Rainbow Pocket measured 4.5 feet tall by 6.5 feet deep by 3 to 4 inches wide; it produced hundreds of specimens. Photo by Bryan Lees.**

> When you stood back and looked into the vug, you saw Christmas. The large red rhombs studded the pocket, with highlights of blue and purple fluorite, yellow calcite and white clear quartz. Breathtaking!!

August 23: In the Tetrahedrite Drift, Bryan and Scott drill and split all day to begin removing the hanging wall side of the pocket. Scott Betz:

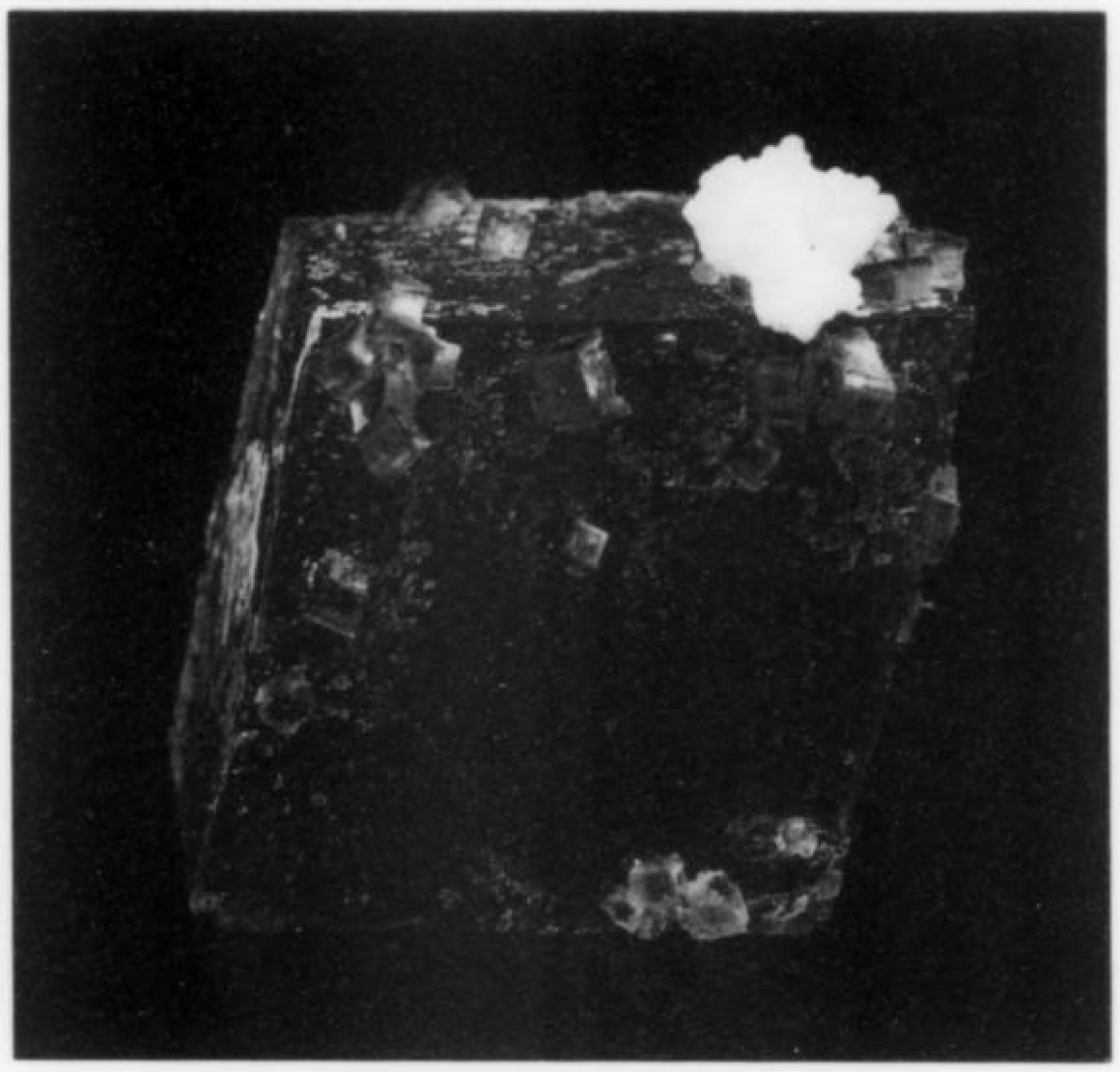


Figure 41. **Rhodochrosite with fluorite and calcite, Rainbow Pocket, Tetrahedrite Drift, 5.1 cm. Many of these "floaters" were recovered from pocket bottoms. These crystals originally grew on the pocket's sides and later detached due to rock stress. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

> Bryan swore us to secrecy. We had to keep that Rainbow Pocket quiet for weeks. Everybody would ask "how'd you do at the mine today?" and it hurt more and more to have to just shrug and say "Oh, so-so . . . nothing great."

August 24: At the end of the day, after 30 split holes, they remove two base plates from the hanging wall of the Rainbow Pocket. The seam goes right through the middle of the spot where the 5-inch rhomb came off. The two plates will be re-attached [to compose the Alma King]. Also, many loose rhombs are taken out. These seem to have grown on the hanging wall, then fallen off. As the pocket seems to have been a water channel, the rhombs are slightly etched, many coated as well with the ¼-inch blue fluorites.

August 27: The Denver Museum of Natural History video crew arrives to video the splitting technique. Joel Bartsch shows up and sees the Rainbow Pocket. Two killer rhodochrosite specimens come out of the pocket's bottom: a 6-inch group of 4 large fluorite-coated rhombs and an undamaged 1½-inch rhomb with purple

Figure 42. **Work begins to repair the "Alma King" specimen at the laboratory in Golden, Colorado. Here, Bill Hawes repairs the two base plates of the "Alma King." Note the red "scar" where the big crystal originally grew. Photo by Bryan Lees.**

Figure 43. **Bill Stone of *The Sunnywood Collection* creates the wood display stand for the "Alma King." Photo by Elsie Stone.**

fluorite and yellow calcite on a 7-inch quartz matrix. Joel opens the bidding right there underground.

August 28–30: Splitting and removal of a large footwall plate, again in two pieces, shows the places where the big crystals will fit back on [this one will become the Alma Rose].

August 31: In the shop, work begins on cleaning and reassembling the two big specimens. Bryan Lees:

> Extraction of the Alma King and Rose specimens was only the beginning of the work. We had the base plates. We had the rhodochrosites that fit back onto them. What we lacked was the technology to put everything back together in such a way as to look original and natural. We decided to hire an expert in fossil preparation in the hopes that such a person could "cross-train" and use those skills to refit, cut, support and match all of the pieces back together again. A knowledge of minerals would also be invaluable. I contacted Bill Hawes and asked him if he would be interested in the project. Bill said he would try. . . . After three months [the winter of 1992/1993] of near-hysteria and frustration, two masterpieces were ready to show the world at the Tucson Show in February 1993 (Figs. 44, 45).

September 3–4: In the Main Stope, the largest shot to date in the mine blows up a 20-inch pocket just past the end of the drill holes. Nothing is recovered.

September 5: In the Tetrahedrite Drift, Bryan and Scott take one more big plate out of the hanging wall of the Rainbow Pocket. It is 3 feet long, 18 inches wide and is shaped like Africa. A very large gem-red rhomb on it is the most perfect of the pocket (Fig. 48). Two fine rhodochrosite miniatures complete the emptying of the pocket.

September 6: In the Main Stope, work with an air chisel reveals signs of another pocket opening up behind the 20-inch cavity blown up on September 4.

September 7: In the Main Stope, a drill hole intersects a 32-inch

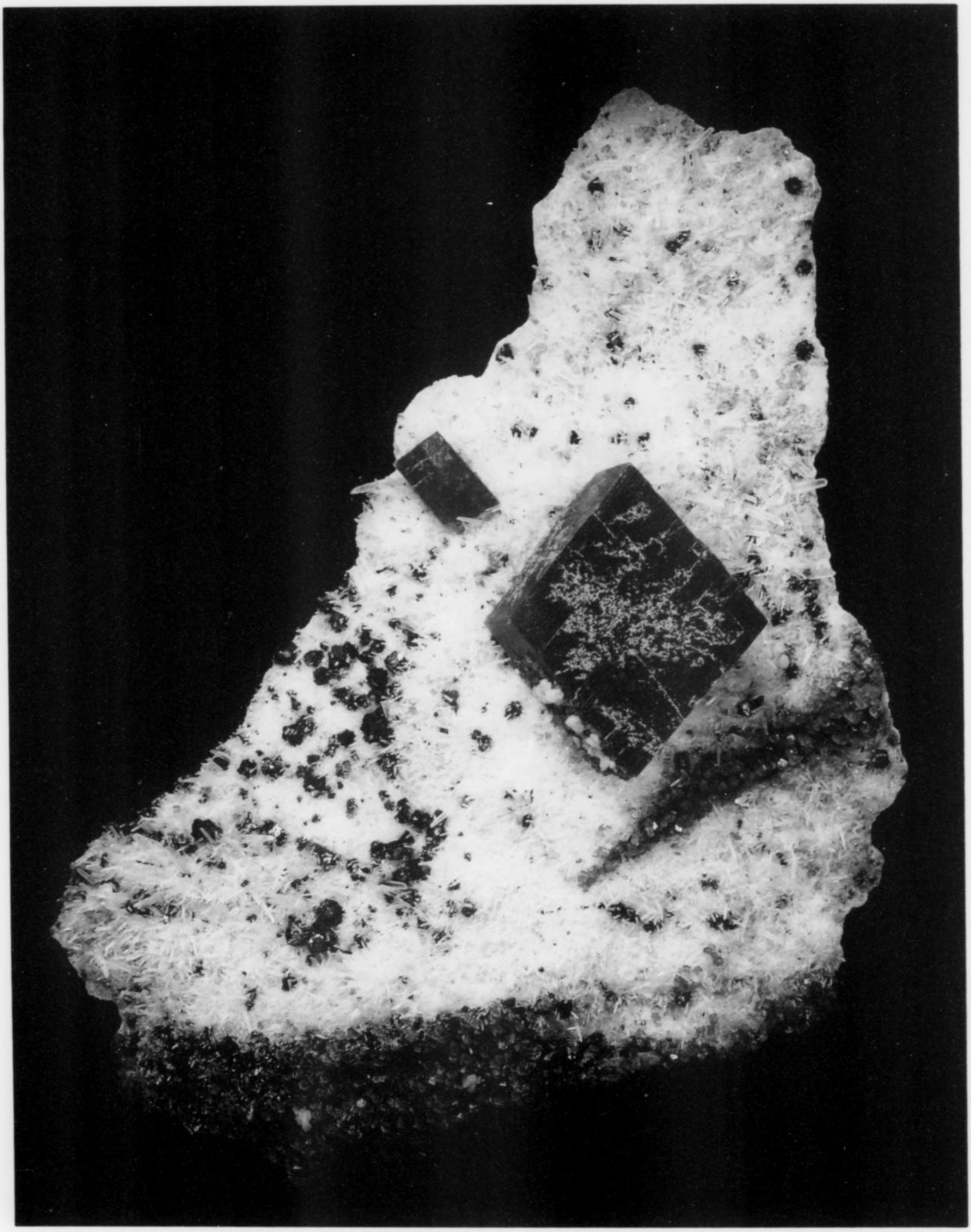


Figure 44. **"Alma King" rhodochrosite after three months of work. The specimen is 66 cm tall; the main crystal is 14 cm on a side. Denver Museum of Natural History specimen; photo by Jeff Scovil.**

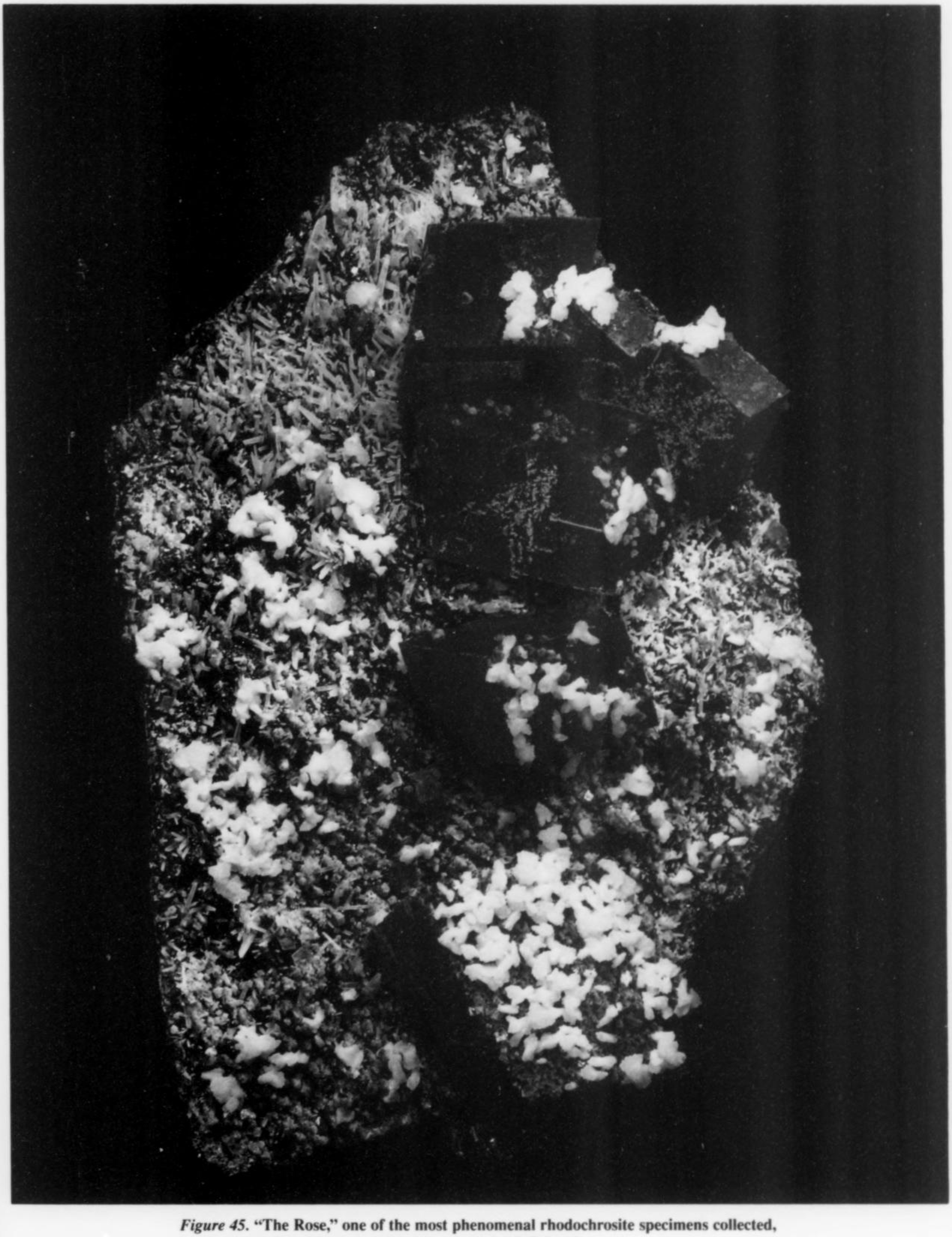


Figure 45. "The Rose," one of the most phenomenal rhodochrosite specimens collected, is 45 cm tall. Rice Museum collection; photo by Jeff Scovil.

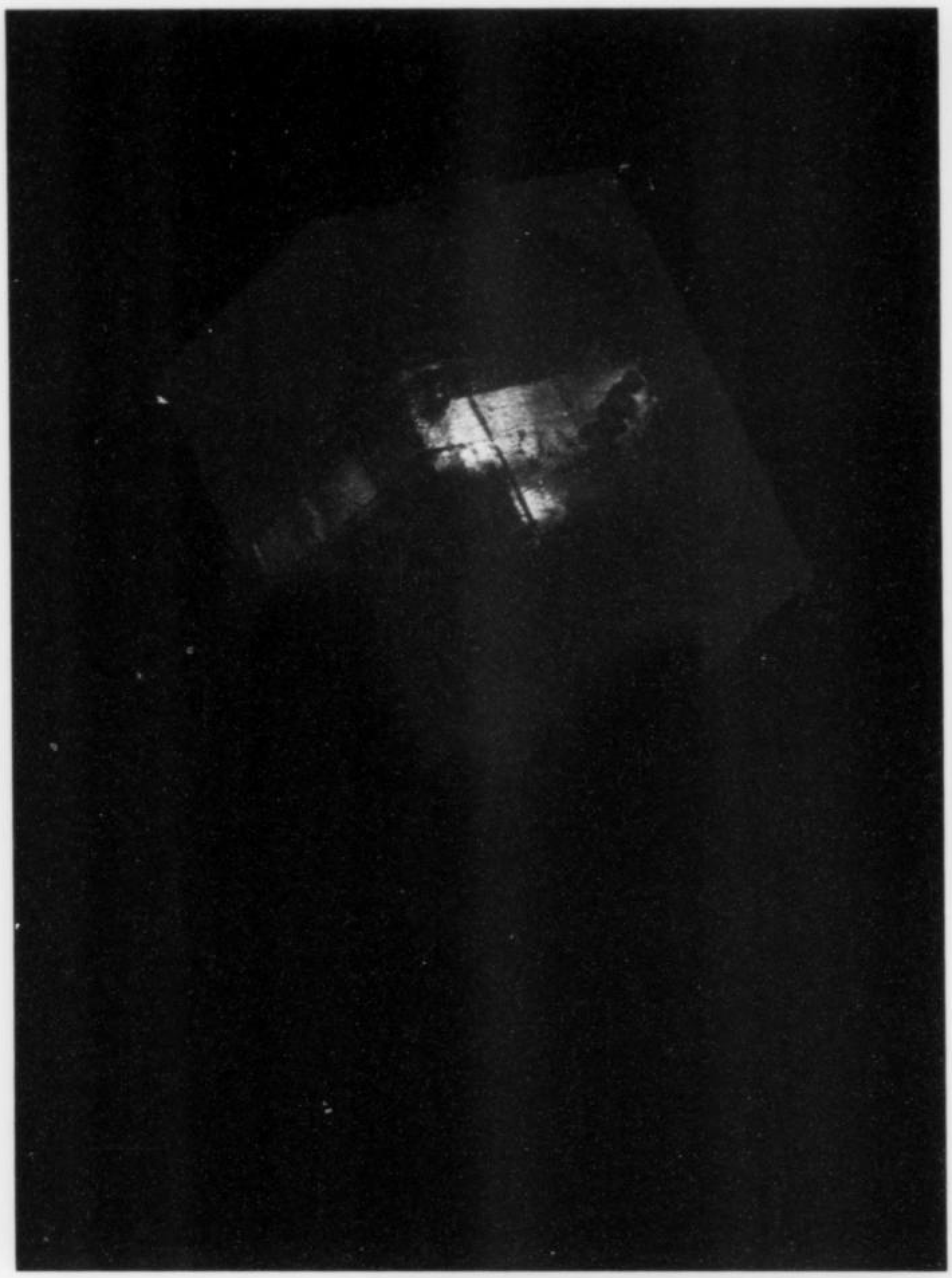


Figure 47. Fluorite on quartz, Rainbow Pocket, 2.5 cm tall. Most of the Rainbow Pocket was coated with fluorite. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.

Figure 46. Fragment of a large crystal from the Rainbow Pocket, backlit to show off its gemminess and transparency, 8.0 cm. Marty Zinn specimen; photo by Jeff Scovil.

Figure 48. The September 5th rhodochrosite specimen, named the "Alma Prince," after extraction and cleaning. The main crystal is 7 cm. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.

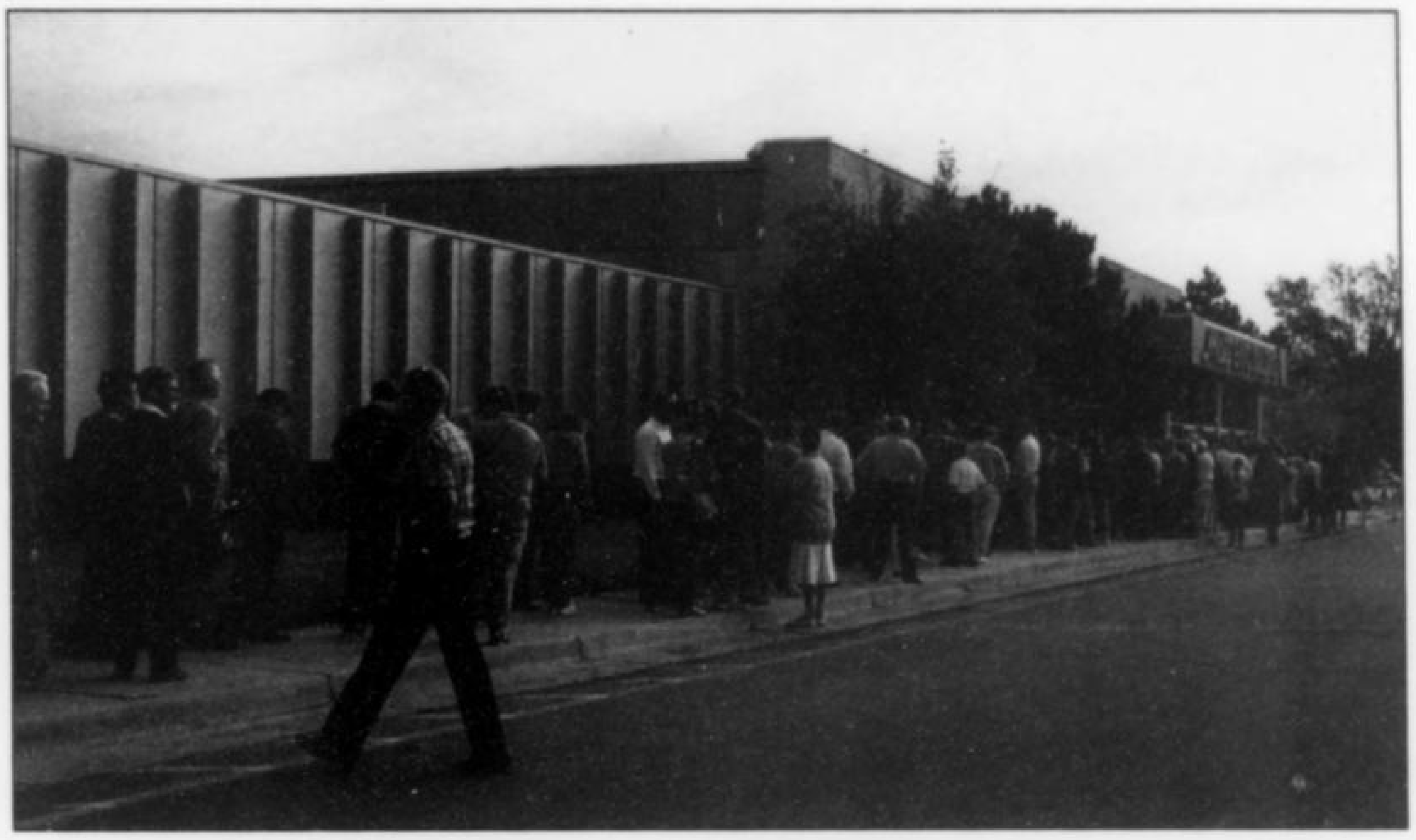


Figure 49. **Queue forming up outside the Denver Gem and Mineral Show for rhodo fever, September 18, 1992. Photo by Bob Jones.**

Figure 50. **Ticket number 1 handed out during the 1992 Denver Gem and Mineral Show rhodochrosite debut.**

Figure 51. **Sweet Home mine production from 1992 about to go on sale at the September Denver Gem and Mineral Show. Photo by Bryan Lees.**

pocket up and to the left of the one that was destroyed. A heavily damaged 2-inch rhomb is stuck at the top of the hole.

September 11–12: The splitter breaks twice. Rory prepares to put in a small round to the right of the potential vug in the Main Stope.

September 18–20: The mine is closed for the Denver Show. Bryan Lees:

> The 1992 Denver Show was very controversial for us. We had just discovered a great pocket of rhodochrosite specimens and word had gotten out to the mineral collectors. We were breaking records getting the material ready at our facility in Golden. Dave Bunk, Dennis Beals, Kathryn and I were working overtime to get everything done. Still we could not keep up. The phone was ringing off the hook. The work involved in getting things trimmed, cleaned and inventoried before the show pushed everyone to their limits. The pocket had been discovered only four weeks earlier.
>
> Our Denver Show goal was to give everyone a chance at the material, so we did not allow anyone to come over to the shop beforehand. Instead, we were going to open the doors at the beginning of the show and let everyone have a fair chance at acquiring a rhodochrosite. On Thursday evening, the Denver Show people came over to our room and informed us that we had better do something about crowd control in the morning. We looked at several options and finally decided to pass out tickets.
>
> In the morning, there was a line outside the Merchandise Mart that had begun forming at 5:00 a.m. At 9:00 a.m., hundreds of people were standing outside our showroom.
>
> Reaction to the tickets was mixed. Most thought that they

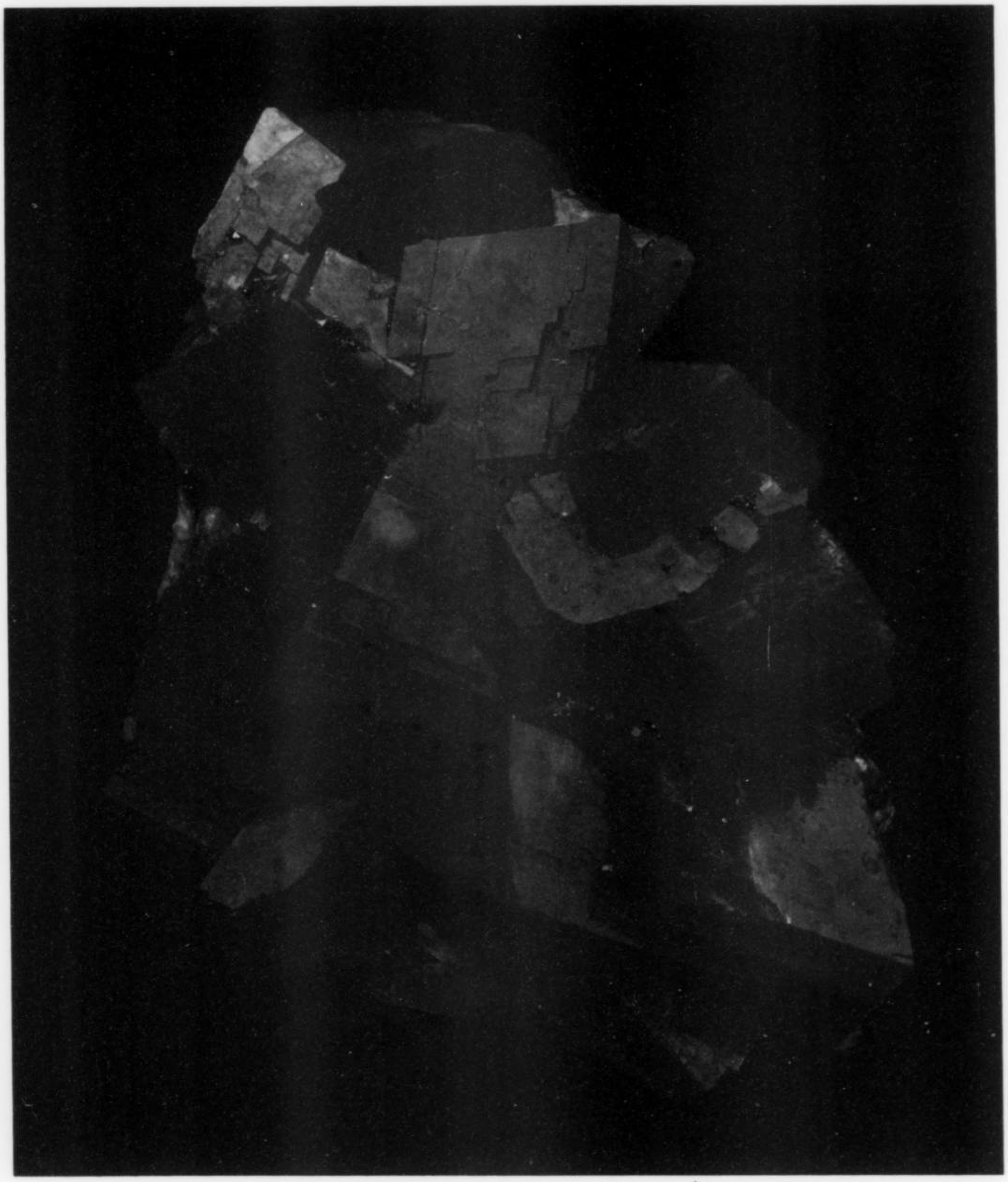


Figure 52. **Rhodochrosite, Good Luck Pocket, 15 cm. Steve Neely specimen; Jeff Scovil photo.**

were a fun diversion from the usual show routine. Some believed that taking a ticket was beneath them. Still others saw the humor in the situation and came up with all manner of amusements, from videotaping the proceedings to selling their tickets to people with higher numbers. The latter move was best executed by John Barlow, who for $20 sold his ticket and place in line for the first showing.

Competition during the first few minutes was fierce. Groups of 20 at a time were admitted to the room. Each group had only 15 minutes to make their purchases. Several people in the first few groups told me that this was one of the most intense things they had ever done. Given the competition in the room, buying decisions had to be made in split seconds. During the first 20 seconds that the room was open, we sold $80,000 worth of specimens. During the first two minutes, we sold $130,000. Fisticuffs nearly happened several times.

Another memory from this day . . . Rory and Scott were handling crowd control outside the sales room when a man wearing a turban walked up and asked to get into the room. Rory politely asked if he had a ticket. The man responded, "I never needed a ticket to get into the room before!" Rory replied, "Well, I'm sorry, but I can't let you inside without a ticket." The man retorted, "Pig-eating infidel!!" and stomped away.

At the end of the show, almost all of the material was sold, and we were wondering, tongue-in-cheek, what we would sell at Tucson in February.

September 20: Back at the mine, Scott and Rory set up a newly purchased splitter and begin to split to within three inches of the pocket in the Main Stope.

September 21 [Discovery of Good Luck Pocket]: Several tour groups visit the mine, four from Europe, including one from the Kongsberg, Norway, mining museum. Then . . . Bryan Lees:

> The day after the Denver Show, Rory and I opened up THE MOST incredible pocket of rhombohedral rhodochrosite crystals ever found. The pocket eventually measured 48 inches deep by 36 inches high by 2 to 6 inches wide. The foot wall was completely covered with ½ to 2-inch interlocking rhodochrosite crystals. The hanging wall consisted of small needle quartz with tetrahedrite crystals and occasional rhombs. In the middle of the pocket was a quartz matrix rind 1 to 2 inches thick with rhodochrosites and tetrahedrite on both sides. These pieces were the most breathtaking and valuable we had ever seen. Celebrating our good fortune, we decided to name the new find the Good Luck Pocket.

September 22: In the Main Stope, a full day of pulling breccia plates and loose crystals out of the Good Luck Pocket yields enough specimens to cover a 6-foot table. All the rhodochrosites are razor-sharp, simple, gemmy rhombs. There are bright tetrahedrites to ⅜-inch and bright druses of chalcopyrite and sphalerite, but no fluorite. Bryan Lees:

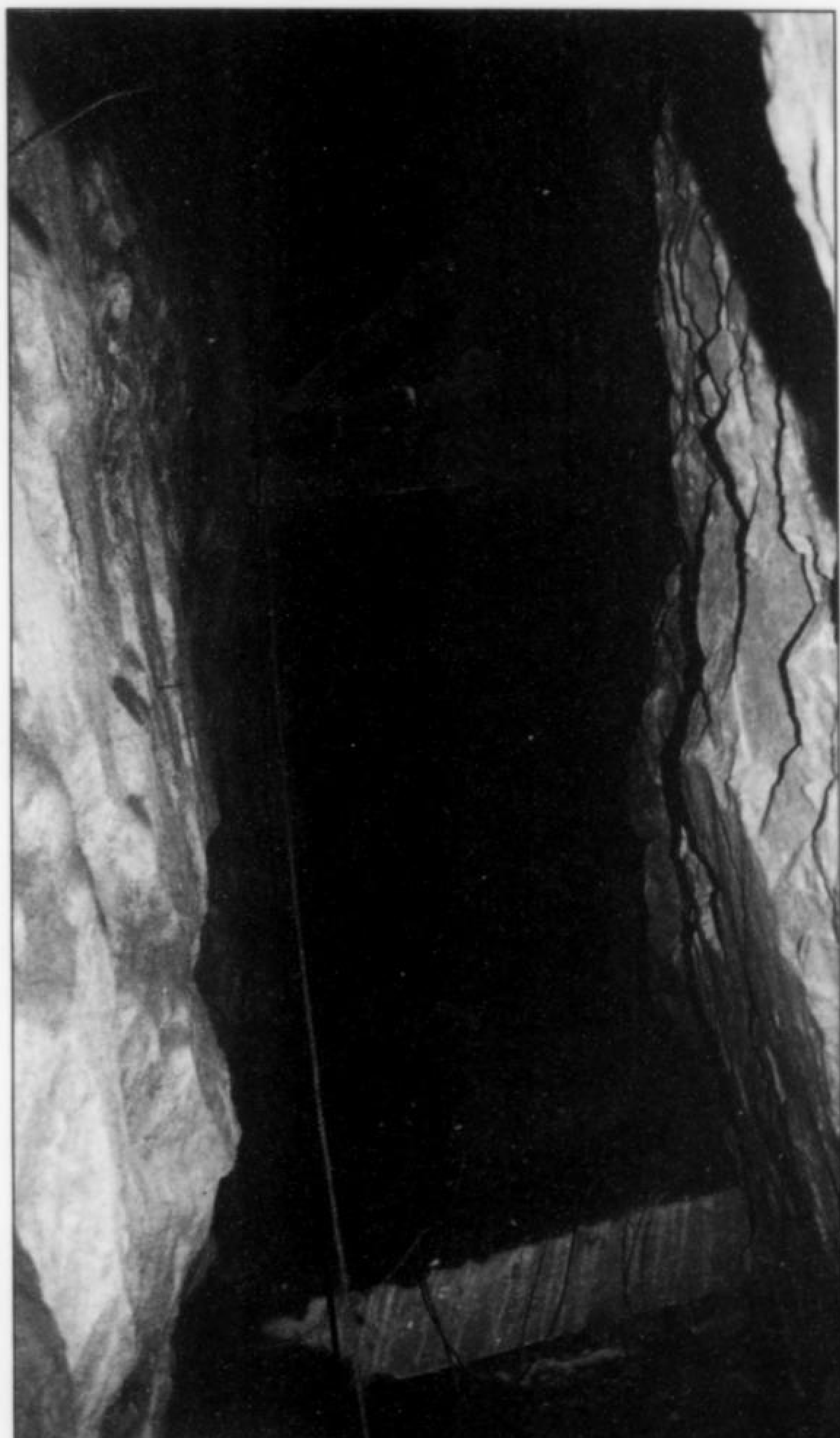


Figure 53. **View looking straight up the Main Stope raise. Mining upwards is called "raising"; most pockets at the Sweet Home have been found in this way. At 11,400 feet elevation, raise mining is no picnic. Photo by Bryan Lees.**

Figure 54. **Bryan Lees reaches into the Good Luck Pocket. Photo by Chauncey Walden.**

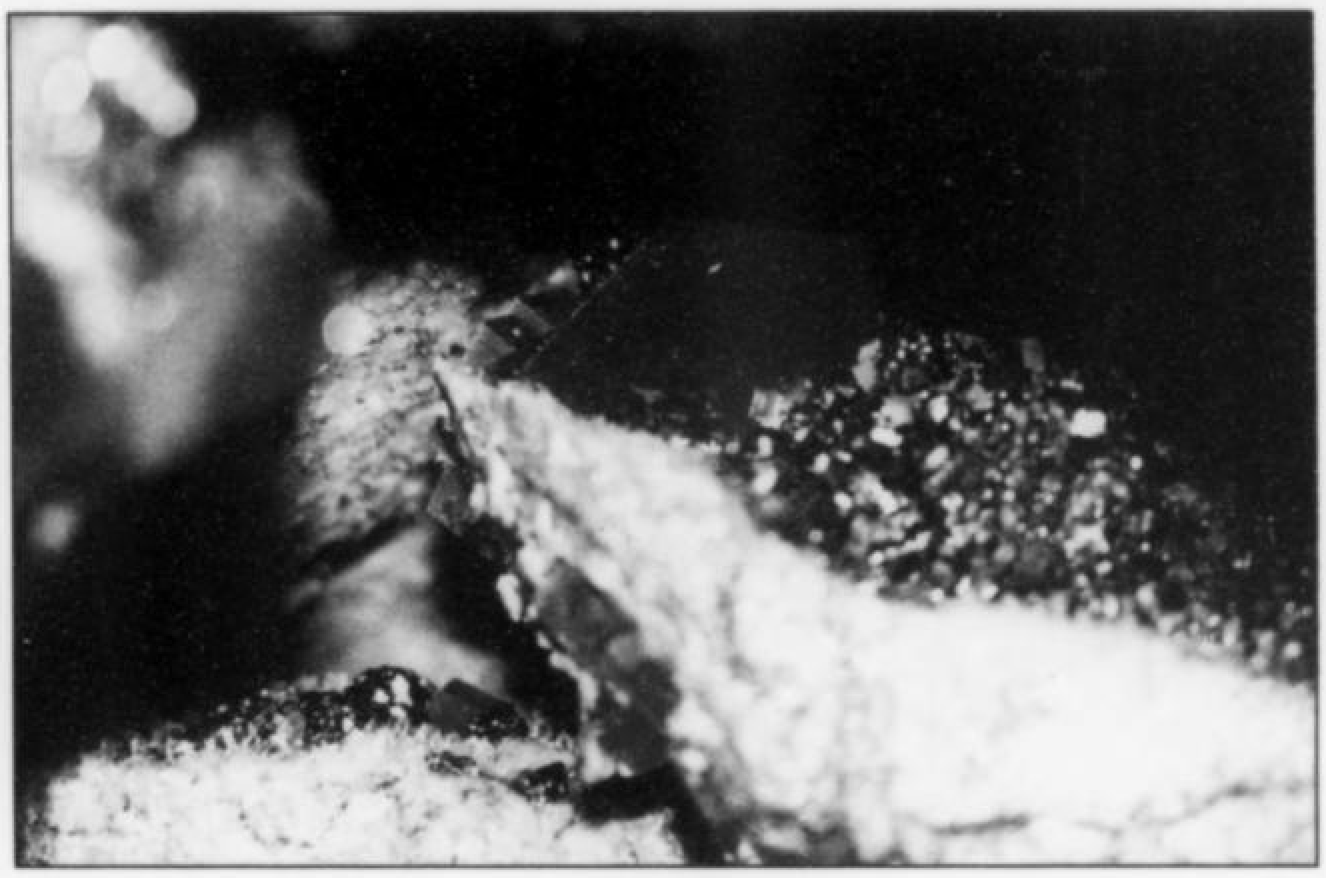
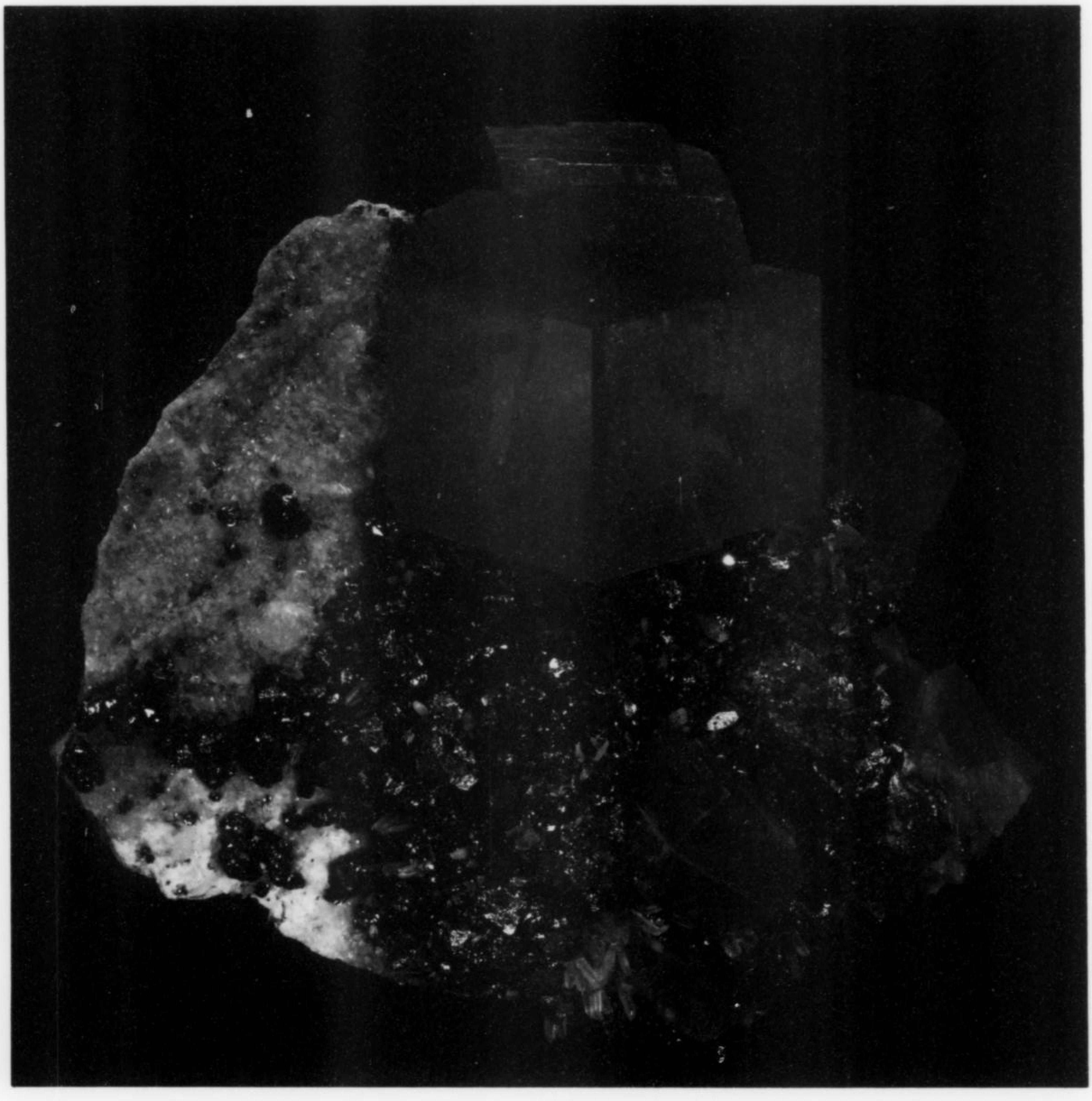


Figure 55. Peering into a portion of the Good Luck Pocket. The "Snow Cone" sits ready to collect. Photo by Bryan Lees.

Figure 56. The "Snow Cone" rhodochrosite, Good Luck Pocket, Main Stope, 17 cm. Sweet Home Rhodo, Inc. collection. Photo by Harold and Erica Van Pelt.



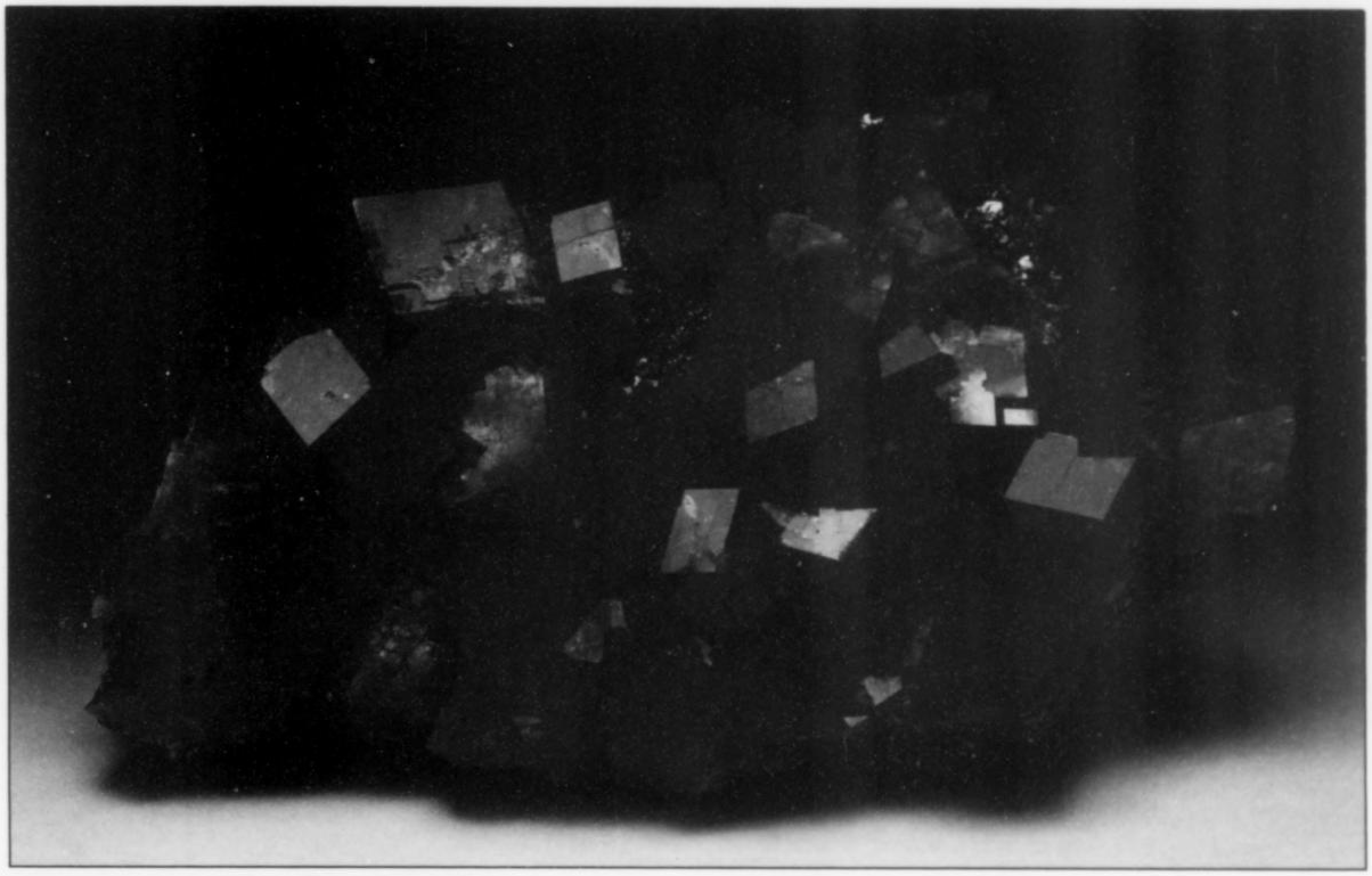


Figure 57. **Rhodochrosite, Good Luck Pocket, Main Stope, 36.5 cm wide, after cleaning. Owner anonymous; photo by Jeff Scovil.**

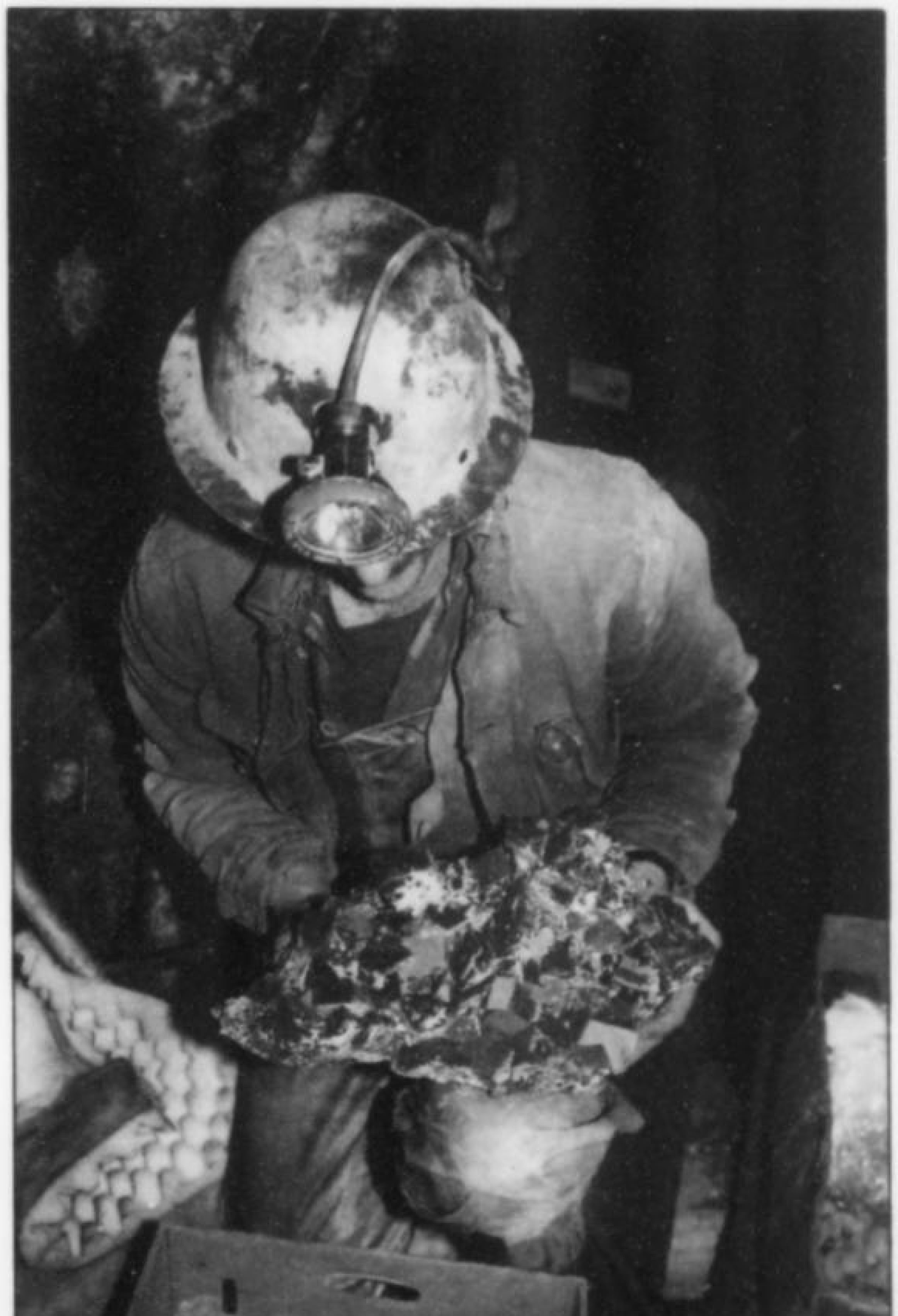


Figure 58. **Fabulous large rhodochrosite from the Good Luck Pocket, 36.5 cm, just collected, and prior to cleaning. Specimen held by Rory MacDonald; photo by Bryan Lees.**

Because of the quartz ridge in the center of the pocket, open space was limited. This resulted in a large portion of contacted and incomplete rhodochrosites. In order to collect the best specimens possible, we had to decide which pieces to sacrifice. Many almost-incredible ones bit the dust in this fashion, and each day we had to take breaks to calm down from the anxiety caused by this wanton destruction.

September 24: In the Tetrahedrite Drift, Scott finds a large vug filled with white clay and takes out 2 to 6-inch needle quartz plates covered with ¼-inch blue-purple fluorite dodecahedrons. The best fluorite this year.

Back at the Good Luck Pocket (Main Stope), Bryan and Rory continue taking out fine specimens, removing the breccia plates and fragments carefully so as not to damage either attached or neighboring crystals. This reminds Bryan of playing pick-up-sticks as a kid—taking everything out from around a target piece. The "sticks" removed in this way are all fine pieces in their own right, but when Bryan finally pulls out the one he's been after, he finds that one side has a perfect 2-inch rhomb on lustrous tetrahedrite crystals and the other side is covered with gemmy red rhombs almost as big.

September 25: With the Good Luck Pocket now over 3 feet deep, another fantastic piece comes out: a 7 x 14-inch matrix of massive and crystallized tetrahedrite completely covered in front

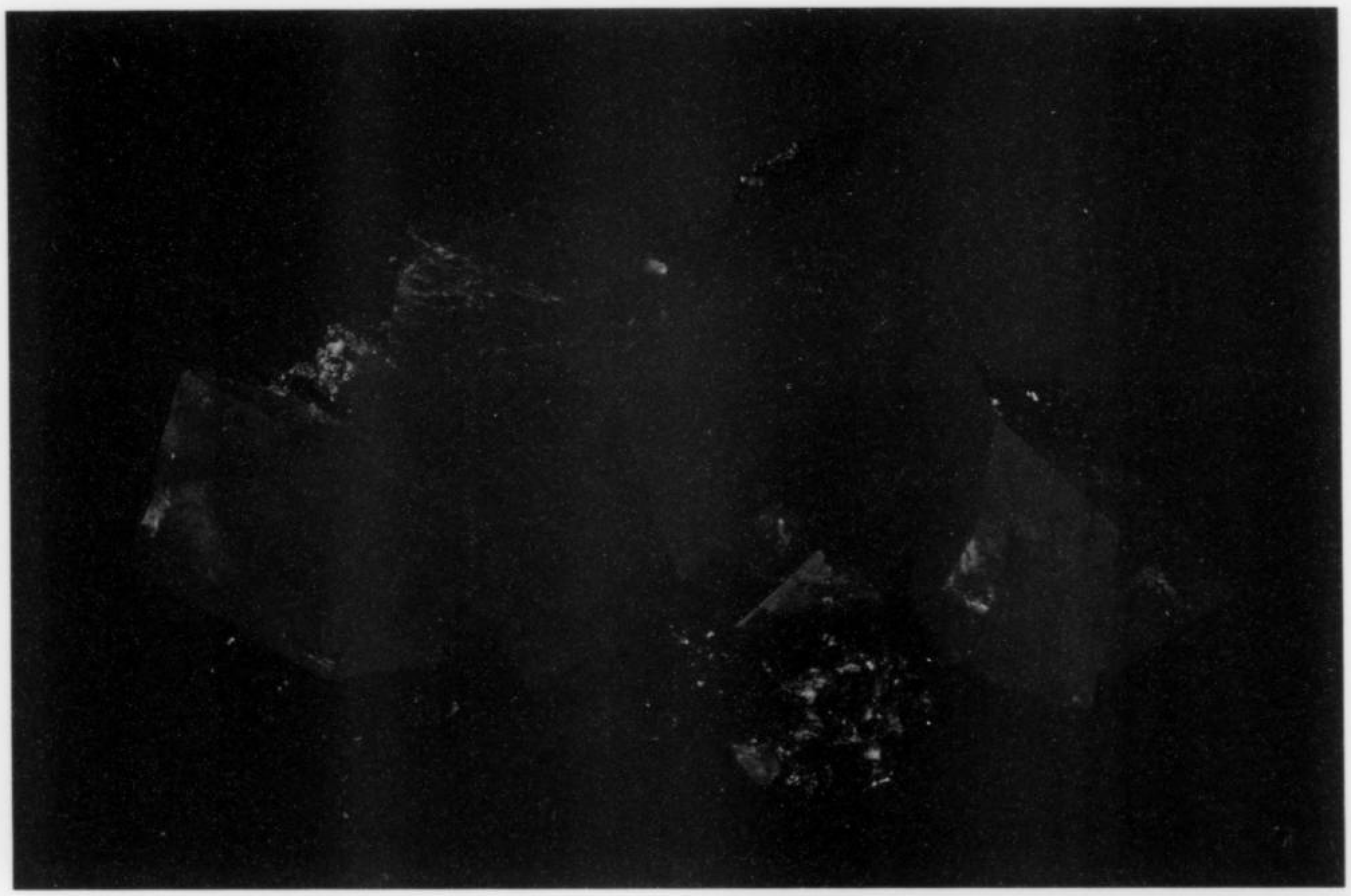


Figure 59. **Rhodochrosite on tetrahedrite, Good Luck Pocket, Main Stope, 11.7 cm. Steve Smale collection; photo by Jeff Scovil.**

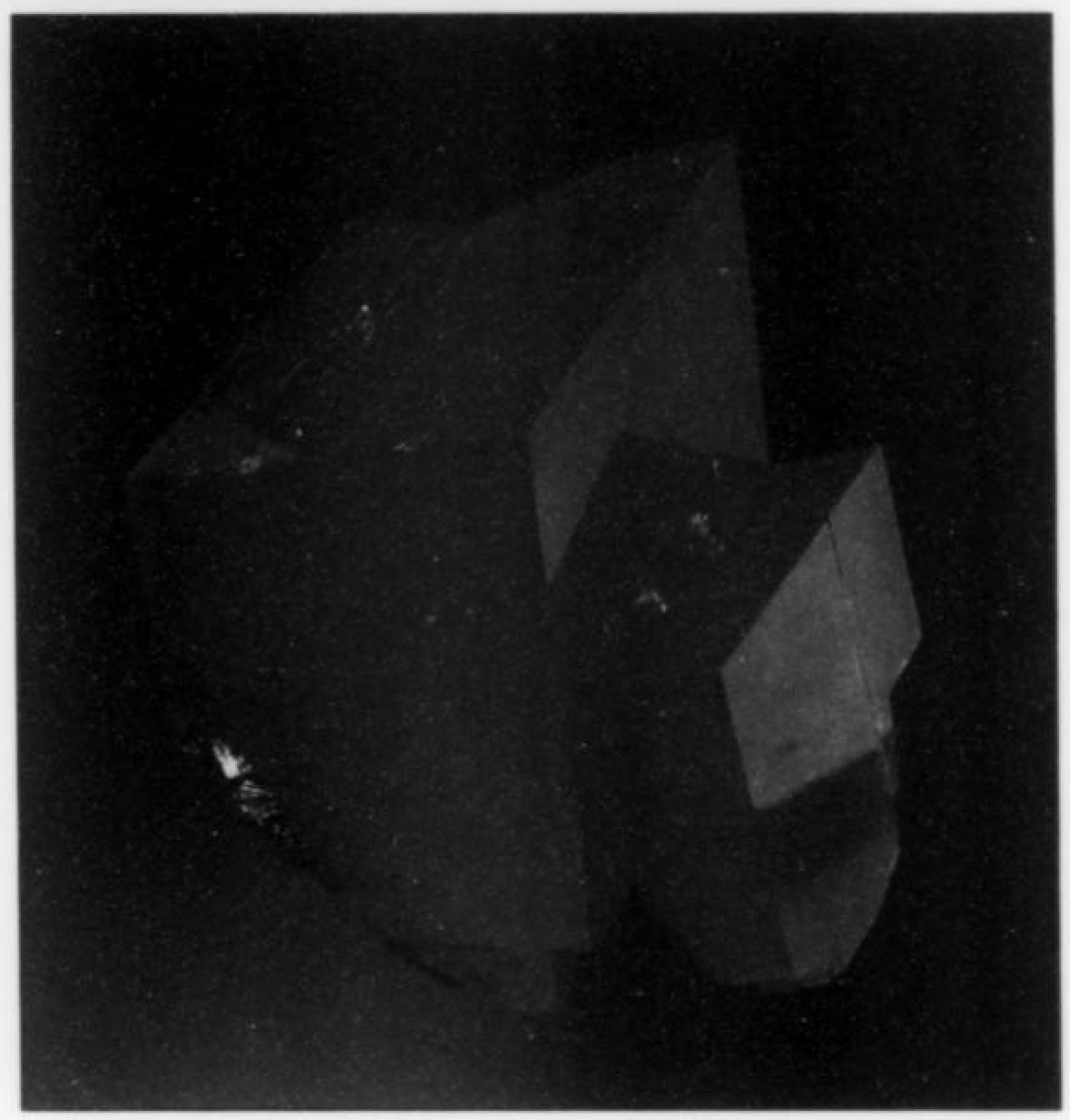


Figure 60. **Rhodochrosite, Good Luck Pocket, Main Stope, 6.2 cm. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

with 2-inch gemmy rhodochrosite rhombs and very little damage [this is the piece—Fig. 57—that was shown briefly at the Denver Show in 1994]. There are also five top small cabinet pieces and 150 single floater rhombs from 1 to 2½-inches. The past three days' production covers a new, 8-foot table.

September 26: In the Main Stope, two killer miniatures are taken out of the Good Luck Pocket. Rory and Bryan drill underneath the pocket and begin to split open its bottom. The hanging wall is now mostly gone and the foot wall is coated with 1 to 2½-inch rhombs.

September 27–October 3: Slow, careful, final stages of recovering the Good Luck Pocket.

October 4–9: Clean-up in both working areas.

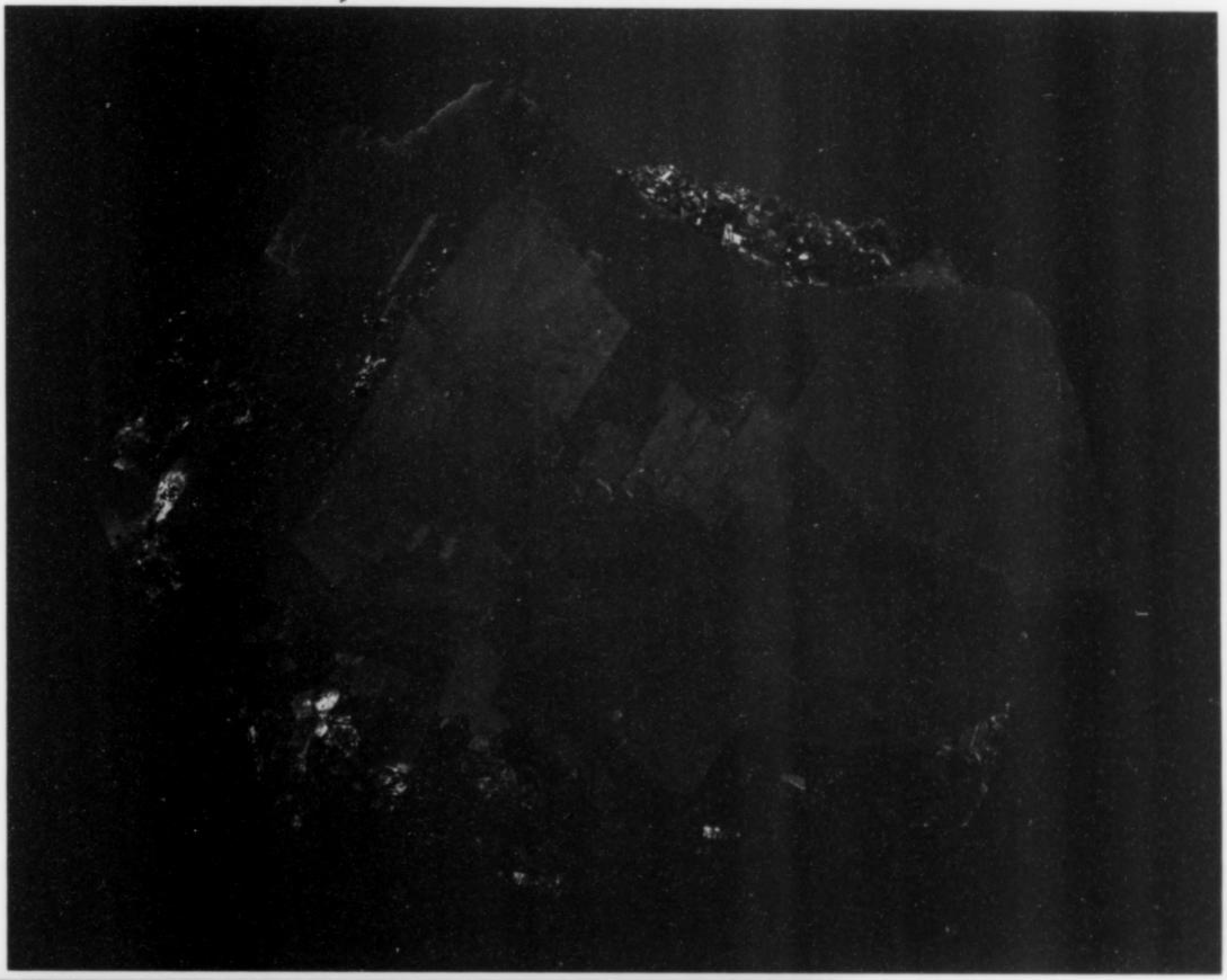
October 9: Bill Silberman and Dean Misantoni tour the mine and decide on three age-dating targets. Numbers later come back dating the rhodochrosite mineralization at about 30 million years ago (see "Geology of the Sweet Home Mine," this issue).

October 10: In the Main Stope, in a wide, massive sulfide exposure, several small rhodochrosite vugs are hit. The crew decides to put off shooting here until next year.

October 11: The mine is closed.

Mineral folk lucky enough to have attended the 1993 Tucson Show will remember the grand debut there of the Alma King and Rose specimens. Let Bryan himself briefly recount the Sweet Home Rhodo, Inc. "peak" experience on this occasion, rivaling that at the '92 Denver Show:

> Selling the Good Luck find at Tucson in February 1993 was exhilarating and exasperating both. With the help of the Tucson Show committee and Marty Zinn, we decided to split the new rhodochrosite find into two parts. The first part would be available at Marty's Executive Inn show and the second at the main show two days later.
>
> I hadn't wanted to pass out tickets again, but Marty Zinn persuaded me to do so anyway, arguing that if I didn't, people would sleep out overnight in front of the hotel in order to be first into the room the next morning Ironically, it turned out that 22 intrepid souls slept overnight outside the hotel room anyway. This, in order to get the first tickets handed out in the morning.
>
> Similar excitement surrounded the unveiling four days later at the Tucson Show. People lined up to get into the booth early in the morning. No tickets this time, the show people handled the flow. Tempers flared and elbows flew but the showing



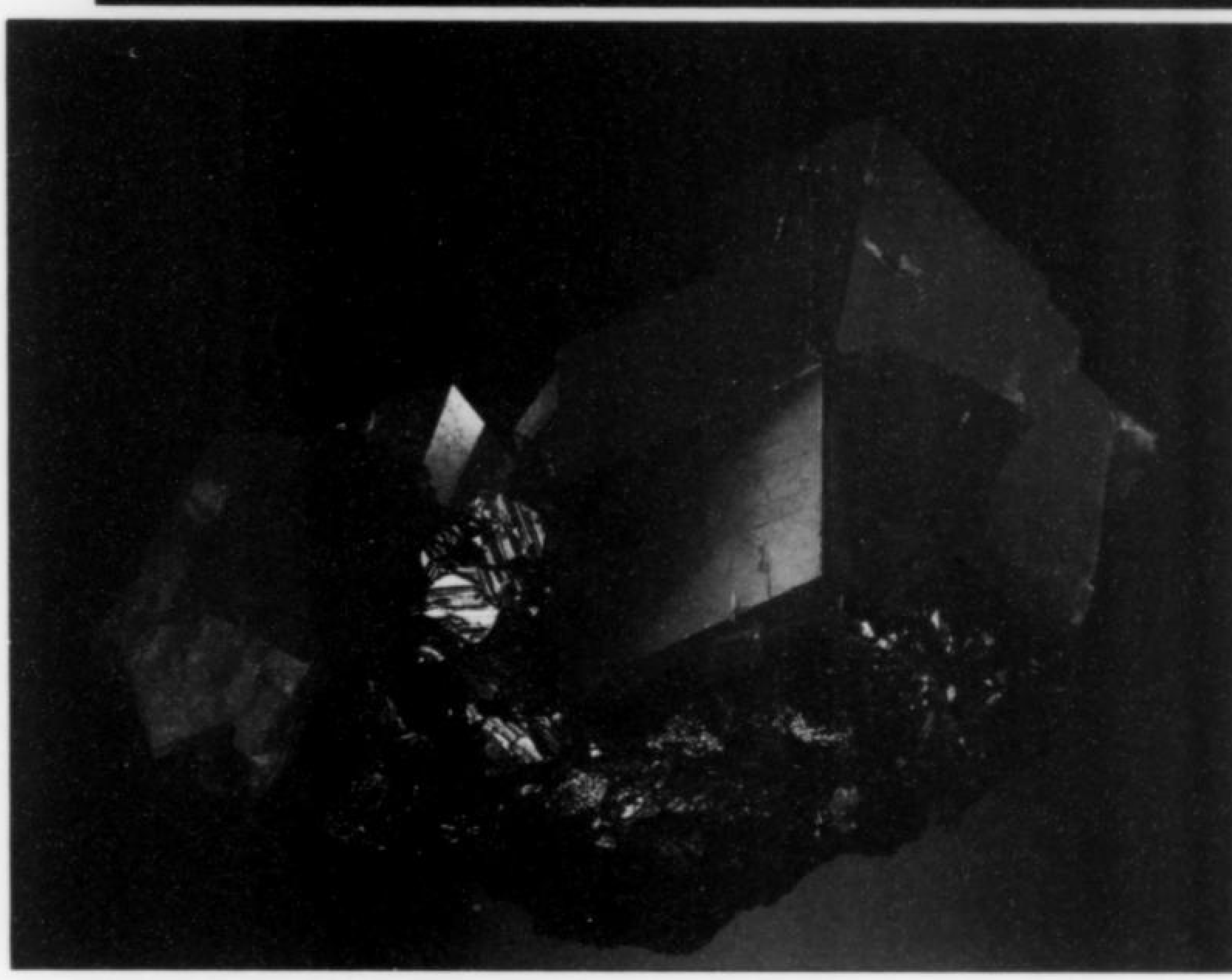


Figure 61. **Rhodochrosite on tetrahedrite, Good Luck Pocket, Main Stope, 10.1 cm. Jack Halpern collection; photo by Harold and Erica Van Pelt.**

Figure 62. **Rhodochrosite on tetrahedrite, Good Luck Pocket, Main Stope, 11.6 cm. Wayne Thompson collection; photo by Jeff Scovil.**

came off without major glitches, thanks in large part to the help of Peter Megaw and Bob Jones, both show committee officers. Also at this show, we unveiled the Alma King and Rose. I will never forget the looks on people's faces as they viewed these pieces for the first time. At one point, they even broke out into spontaneous applause. It was the most exciting moment I have ever had at a gem and mineral show."

Long-experienced collectors, curators, journalists and others who thought they had long since "seen it all" in the super-specimen department were, for once, tongue-tied, numbed and bedazzled. So high hopes for the '93 collecting season belonged now not just to the Sweet Home explorers themselves, but to the whole mineral world. Unfortunately, the new season would prove to be no match for the earlier one. Only one pocket, the Blueberry, began to edge

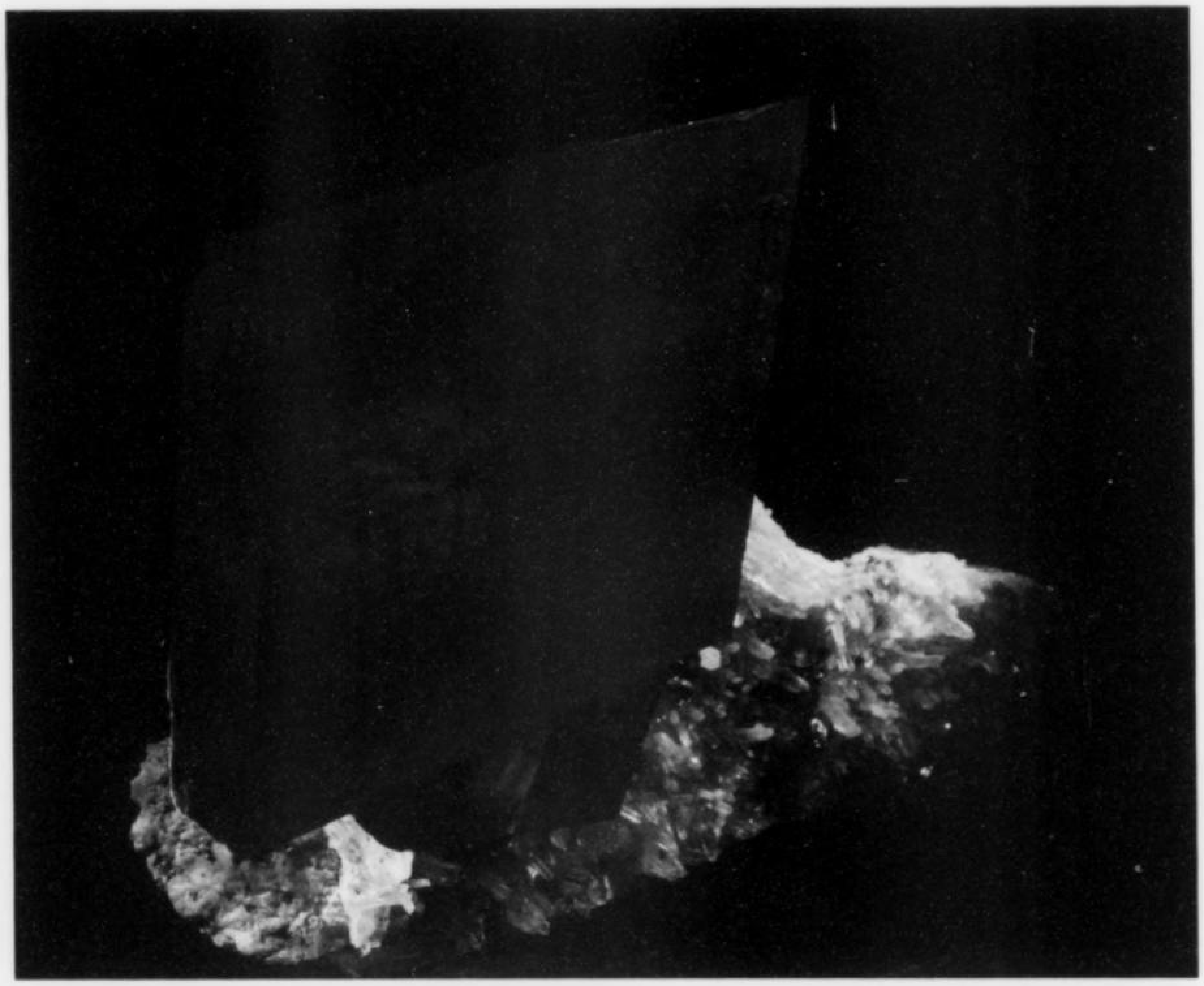


Figure 63. Rhodochrosite on quartz, Good Luck Pocket, Main Stope, 6.1 cm. Helmut Bruckner specimen; photo by Helmut Bruckner.

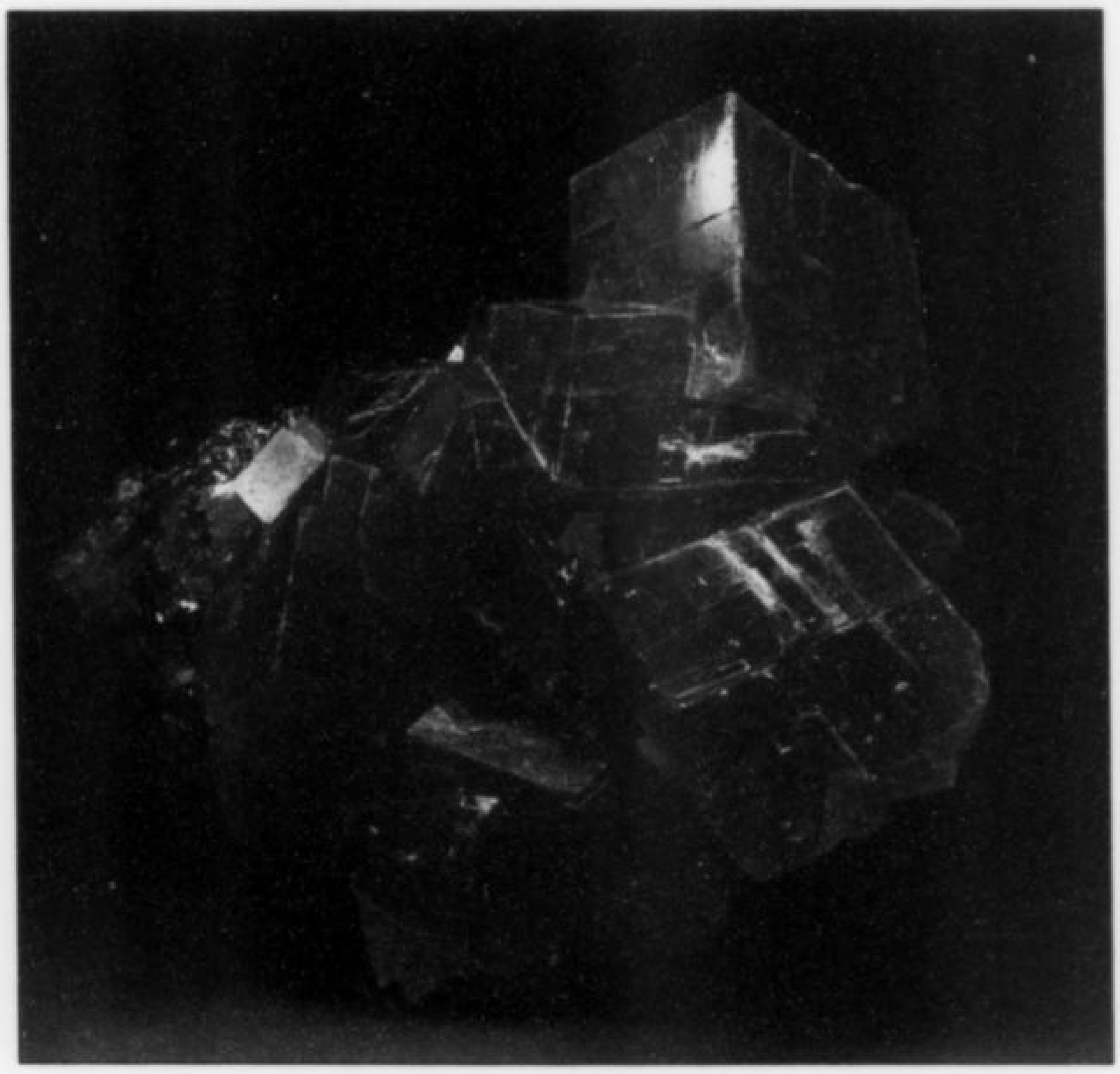


Figure 64. Rhodochrosite, Good Luck Pocket, Main Stope, 15.5 cm. National Museum of Natural History, Paris, France, collection; photo by Jeff Scovil.

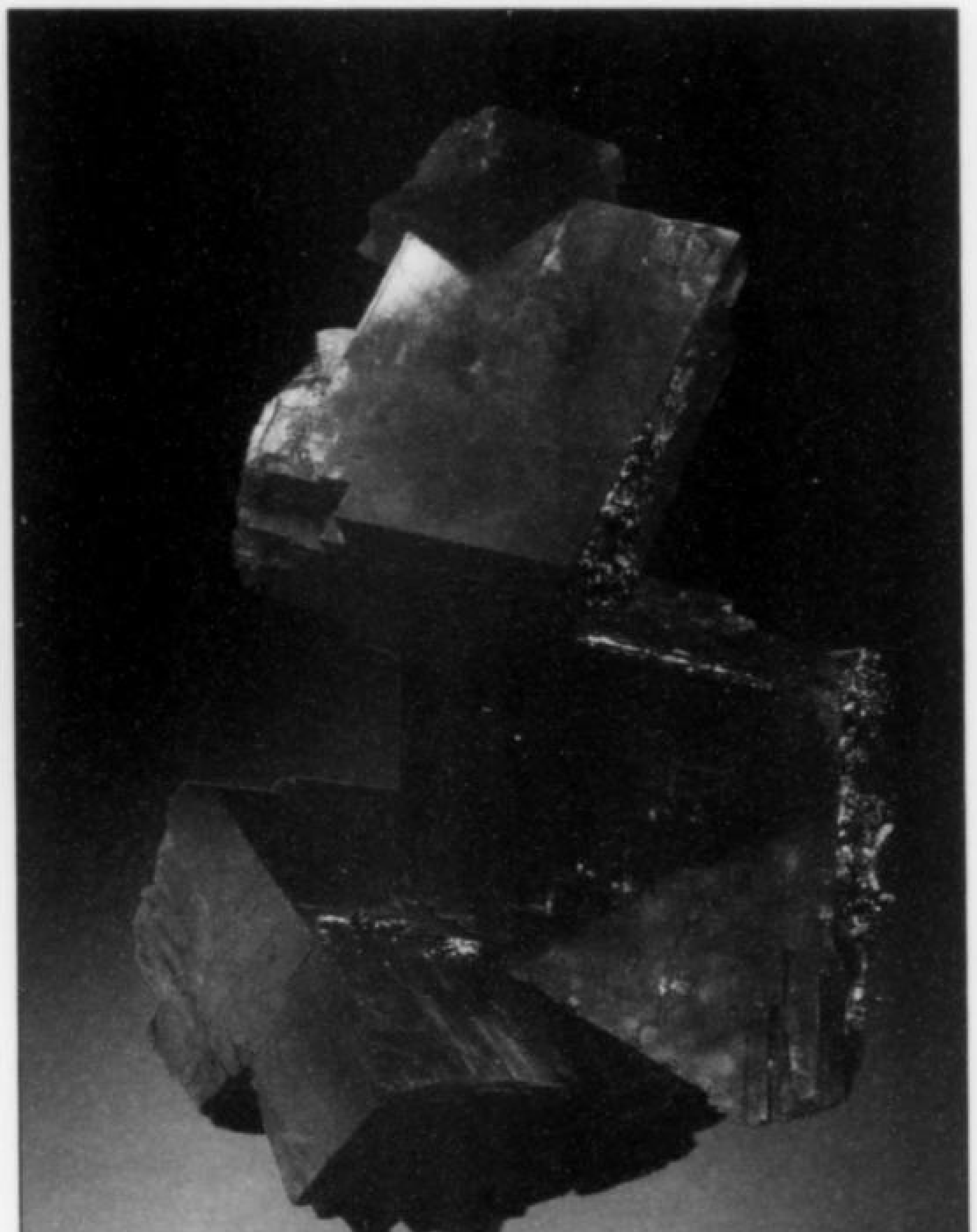


Figure 65. Rhodochrosite, Good Luck Pocket, Main Stope, 11.0 cm. Natural History Museum of Los Angeles County collection; photo by Jeff Scovil.

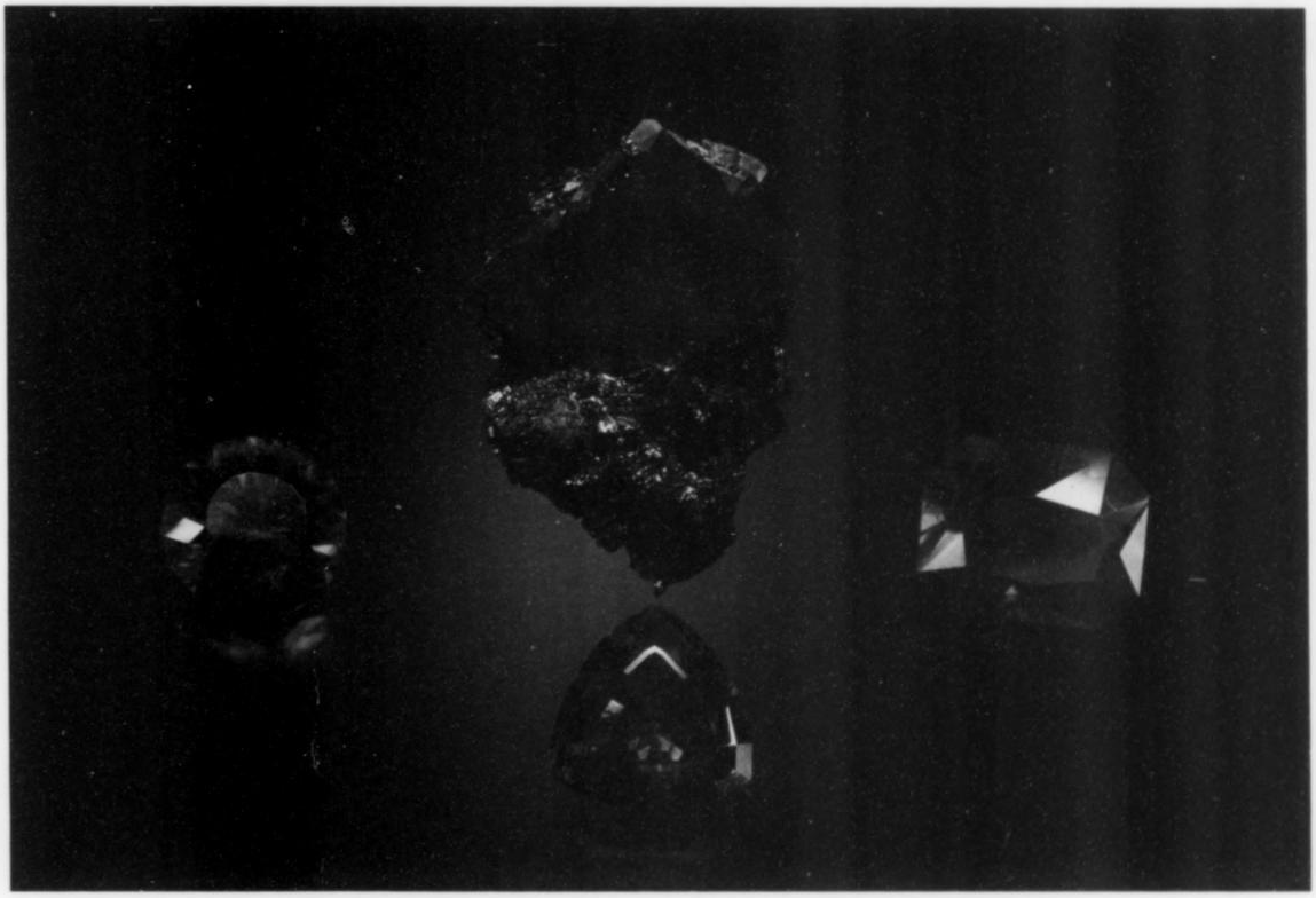


Figure 66. **Rhodochrosite with cut stones, Good Luck Pocket, Main Stope; crystal is 2.5 cm. Gene Meieran specimen; photo by Jeff Scovil.**

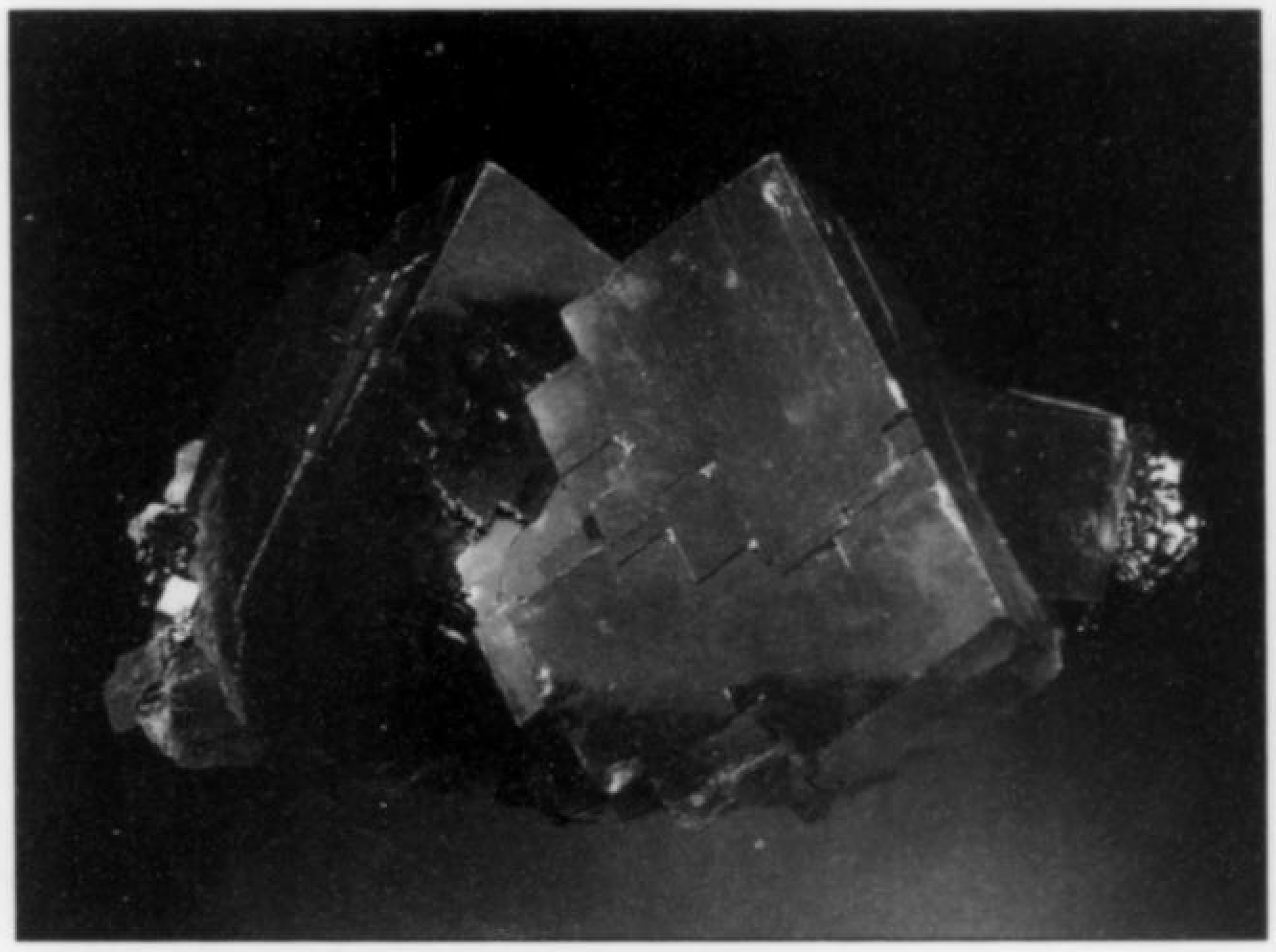


Figure 67. **Rhodochrosite, Good Luck Pocket, Main Stope, 10.1 cm wide. Houston Museum of Natural Science specimen; photo by Jeff Scovil.**

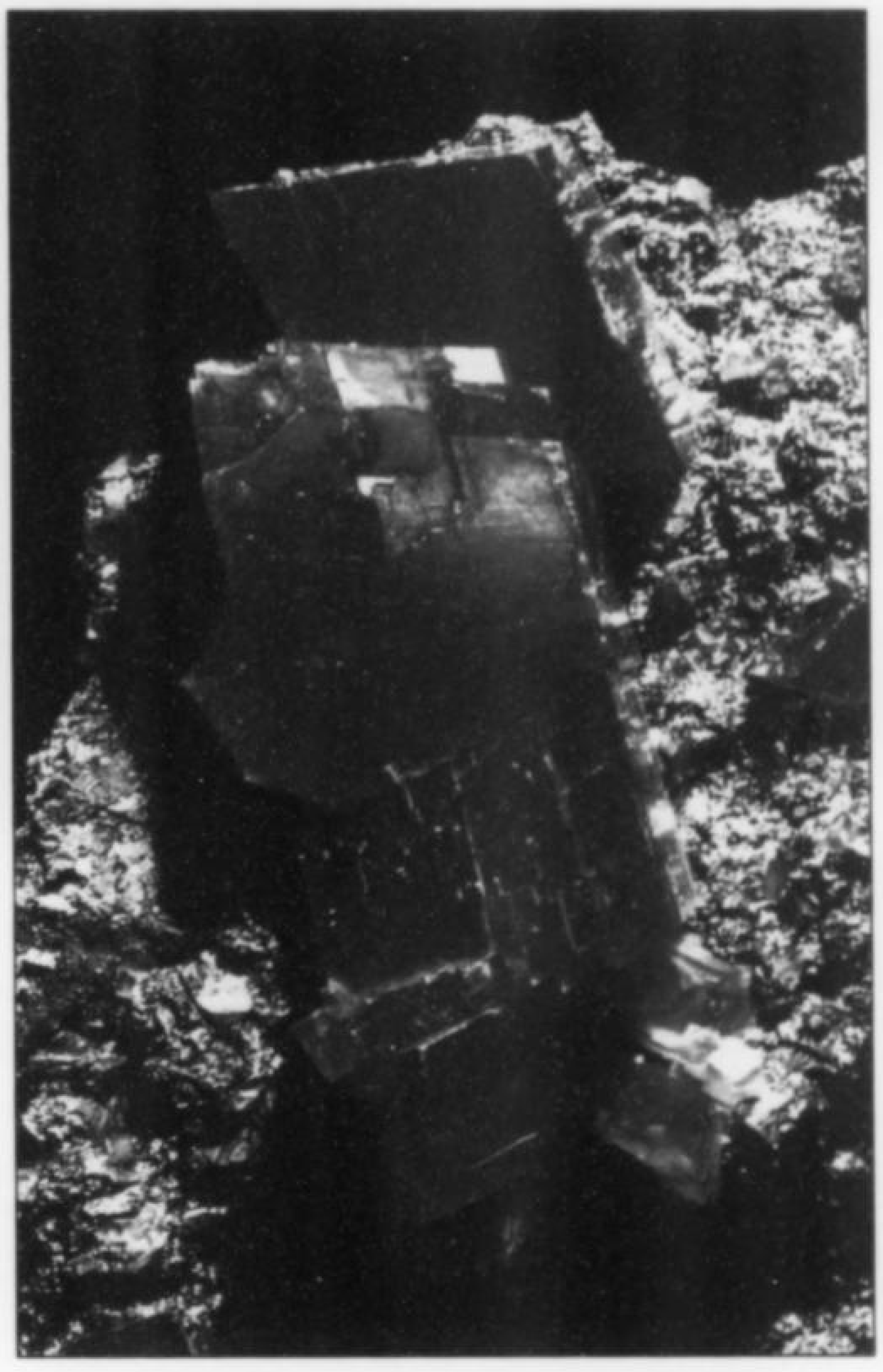


Figure 68. **Rhodochrosite, in crystals to 6 cm, from the Good Luck Pocket. Carnegie Museum of Natural History collection; photo by Debra Wilson.**

up on greatness as defined by earlier standards. Moreover, this would be the most physically grueling, demanding season of all for the Sweet Homers.

THE 1993 SEASON

May 15: The winter in the mountains was the worst in eight years. On May 10, they tried to plow the road to the mine but were hit with a cease-and-desist order from the Forest Service, which feared they would damage the road. Several days later the order was lifted. On May 19, all hands arrived at the mine and found ten feet of snow at the portal. By the 21st, three weeks behind schedule, they were underground, but were hit with a mine inspection order from the Mined Land Reclamation Bureau (MLRB), whose people showed up on June 3 and issued what was, after all, a good report.

The Main and Tetrahedrite stopes were on vertical structures which produced the Good Luck and Rainbow Pockets respectively. In order to find more rhodochrosite, we had to continue straight up.

None of us knew how high we could go with the equipment we had at the time. Without a raise climber (a device like an elevator installed underground), upward movement would be extremely expensive, tedious and physically exhausting—as we all were about to find out.

June 16: Peter Giamou from Multi-View comes from Canada to do a ground-penetrating radar (GPR) test.

June 18: Scott readies the working area in the Tetrahedrite Drift. Rory begins drilling for an ore pass into the Main Stope vein.

June 22: Scott shoots in the Tetrahedrite Drift and hits a nice small vug with clean ½-inch rhodochrosites on clear lustrous quartz needles.

Figure 69. **Geophysicist Peter Giamou from multiVIEW Geoservices, Inc. readies his Ground Penetrating Radar (GPR) gear for an underground survey of the Sweet Home mine. The two antennae are in front of the truck, and the "black box" receiving gear is the lower right. Photo by Bryan Lees.**

May 28: The first round of the season is shot in a tool-cut (storage) area of Crosscut No. 3.

June 3: The MLRB shows up, likes the operation but says "we will have to go before the Board" for a ruling on the mine's permanent status.

June 7: Rory collects a nice small vug at the tool-cut site on Crosscut No. 3. Six very good pieces with ¼ to 1-inch semi-lustrous rhodochrosites and ⅜-inch purple dodecahedral fluorites on needle quartz.

June 8: A new miner, Mike Warren, comes on duty.

June 9: In Crosscut No. 3, rock bolting is carried out on some bad ground, then shooting up behind the tool-cut in hopes of more vugs like the one on June 7.

June 10: Nothing shows up in Crosscut No. 3 and the ground becomes more dangerous. They decide to abandon the area. Bryan Lees:

> After the success of the 1992 season, we were getting a little cocky. We found two major pockets by following certain kinds of vertical geologic structures. So, it followed, all we had to do was follow these same structures during our 1993 season.

June 28–29: Rory collects some good fluorites in the ore pass area near the Main Stope including a 12 x 12-inch plate coated on both sides with small crystals.

July 7: Shooting on a raise in the Tetrahedrite Drift is expected to take them up into the anomaly detected by ground-penetrating radar (GPR) three weeks ago. This work is concentrated straight above the Alma King find and eventually becomes the Tetrahedrite Stope. A pocket is exposed, just slightly off the anomaly area, with a 3 x 4-inch rhodochrosite rhomb attached to its left side. Geologists Bill Silberman, Dean Misantoni, and Russell Hamman start a new surface mapping project.

July 8: Tony Kampf of the Los Angeles County Museum comes up for a mine tour. Bryan can reach his hand 3 feet into the new vug in the Tetrahedrite Drift and cannot touch its end. They decide to drill split holes but Scott's drill goes down and Rory's throws a rifle nut. Lightning strikes very near the mine.

July 9: In the Tetrahedrite Stope, Scott and Bryan split around the vug. They can see the 3 x 4-inch rhomb. Peter Megaw and his sons visit.

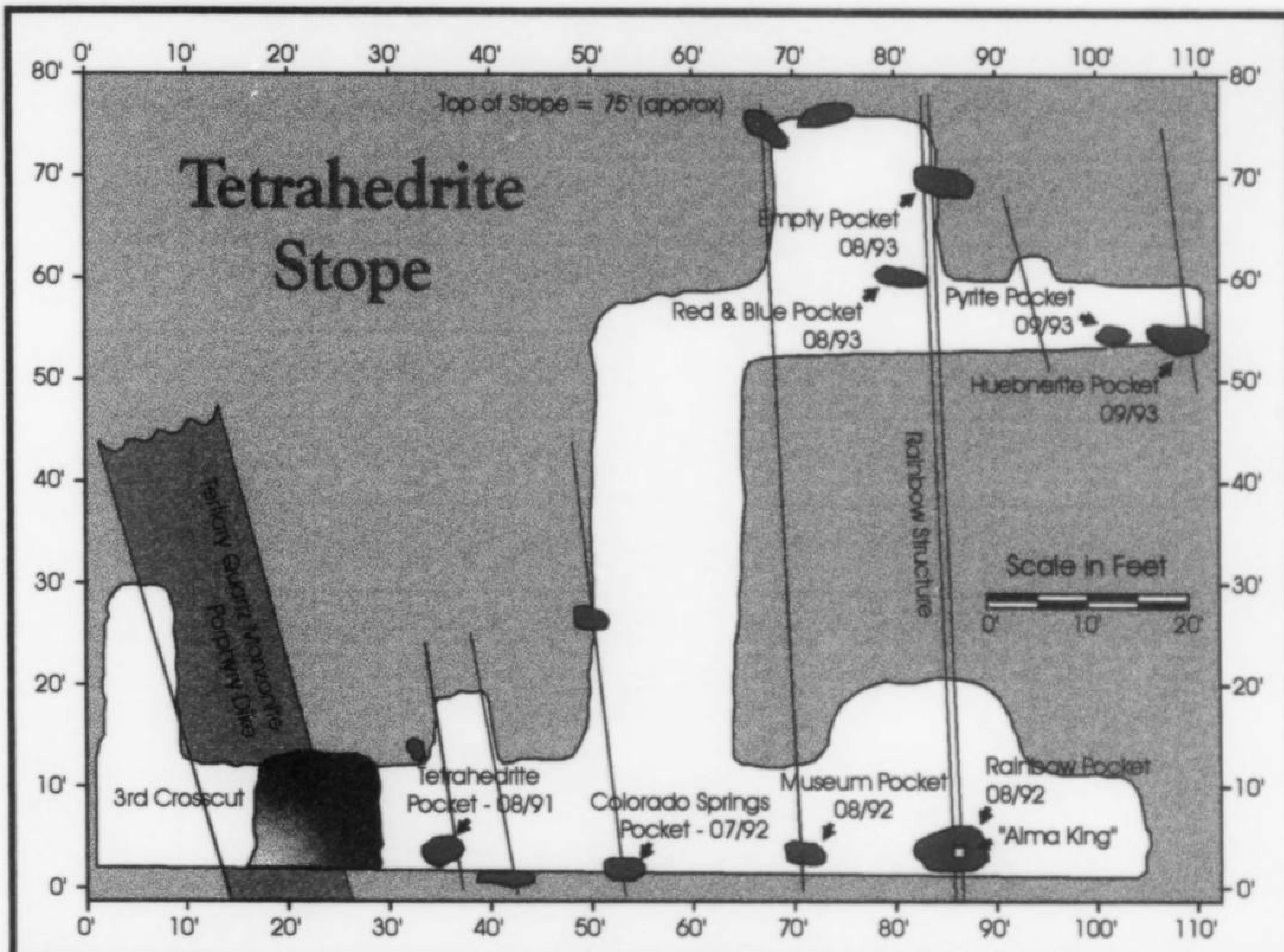


Figure 70. **Section of the Tetrahedrite Stope in 1993, looking east. Graphics by Bryan Lees and Bill Tanaka.**

SWEET HOME MINE
ALMA
COLORADO

July 14: In the Tetrahedrite Drift, the big crystal breaks off the wall. Several days of work lost! The vug is about 15 x 12 x 3 inches.

July 15: The surface geology work is finished.

[The next 2½ weeks have no daily journal entries. It is "an extremely difficult and frustrating time." They are working in two areas and finding nothing. Everyone is fatigued. Bryan decides to spend 5 days a week at the mine. Mining straight up into the GPR targets is proving costly, with no significant specimen inventory coming in.]

July 31: Fifteen members from the Mile High Rams mineral club come for a mine tour.

August 3–5: Rory MacDonald finishes work on the ore pass and man-way into the Main Stope. It will now be possible to go up another 100 feet from the present 80-foot level.

August 6: In the Main Stope, they shoot up towards the GPR targets and hit three small vugs. Sulfides are widening upward.

August 10: In the Main Stope, the widest sulfide streak yet is seen as the vein continues to widen upward. Four drill holes intersect a vug 5 feet up: "the vug makes water for about 10 minutes."

August 13: John Barlow takes a mine tour.

August 17: In the Main Stope, a shot to bring down a large hanging wall slab works, but damages a small exposed vug. The vug has some nice purple dodecahedral fluorites to 1 inch, one of them attached to a ¾-inch rhodochrosite rhomb. The GPR target should now be 3 feet up.

August 20: In the Main Stope, much pyrite is exposed. Rory drills into a large vug with silica-coated rhombs. In the Tetrahedrite Drift, Scott exposes a pocket with coated rhombs and good cubic purple fluorites.

August 21: Three mine tours, one of them for the Colorado Mineralogical Society.

August 25: In the Tetrahedrite Stope, Bryan finds two pockets when Scott slushes out scram. Some medium-grade small rhodochrosites and some ½-inch dodecahedral fluorites come out. They drill a face with much pyrite and hit several vugs 3 to 5 feet back. They are now about 50 feet directly above the site of the Rainbow Pocket.

August 31: Bryan brings up the Sweet Home Lager [see later] from Denver and stashes it underground to age.

September 2: Continued shooting shows nothing new.

September 3: In the Tetrahedrite Stope, Bryan and Scott drill into two vugs which release water. If they are connected, the whole vug is 6 feet across.

September 4: The big pocket breached yesterday seems to be a deep, narrow seam filled with clay, mud and breccia. Washing up into it with a hose produces a huge load of decomposed pyrite and rhodochrosite. Then, a piece comes out with 1-inch rhodochrosites on a beautiful bed of ¼-inch purple fluorites.

Figure 71. **Rory MacDonald brings a load of rock out of the mine. These loaders, called LHD's, carry about 4,000 pounds of rock. Each day, the loaders bring between 20 and 40 loads of rock out of the mine. Photo by Bryan Lees.**

September 7–9: In the Tetrahedrite Stope they timber up a new raise to open up the new pocket system—the Red and Blue Pocket. The seam fails to widen and only produces fair to low quality rhodochrosite/fluorite specimens.

September 10: Rory hits some small vugs in the Main Stope.

September 13: Continued small production, exploration in both areas. There are 6 feet of snow on the ground.

September 13–19: The Denver Show period—it's four days this year. Bryan is nervous, as they have not had a major '93 find. Fortunately, they still have material from the '92 finds and by Saturday afternoon, sales are almost as high as last year's. Then there is the unfinished Big Business . . .

Bryan Lees:

> Ever since the Tucson Show, rumors abounded regarding the price being asked for the Alma King and Rose specimens. It was interesting listening to the various opinions being expressed. Figures from $200,000 to $1,500,000 for the pair were bandied about. Everyone, it seemed, had an opinion.
>
> After the 1993 Tucson Show, Dave Wilber and I began a quiet effort to sell the two specimens. Our goal was to sell them as a pair. We were concerned that, with a rather small market for something so expensive, damaging rumors could reduce the saleability of the pair. After all, prices like these had never been asked for a non-gem mineral specimen. The would-be buyer was faced with the problem that there were few specimens in the mineral world to compare price-wise with these two.
>
> True to our fears, by June 1993 the general opinion in the market was that the pieces were just too expensive. That was not good. Our mining costs were such that if we could not sell the pieces for the amount we were asking, we could not operate the mine into 1994 anyway . . . so why lower the price?? We decided to raise the price.

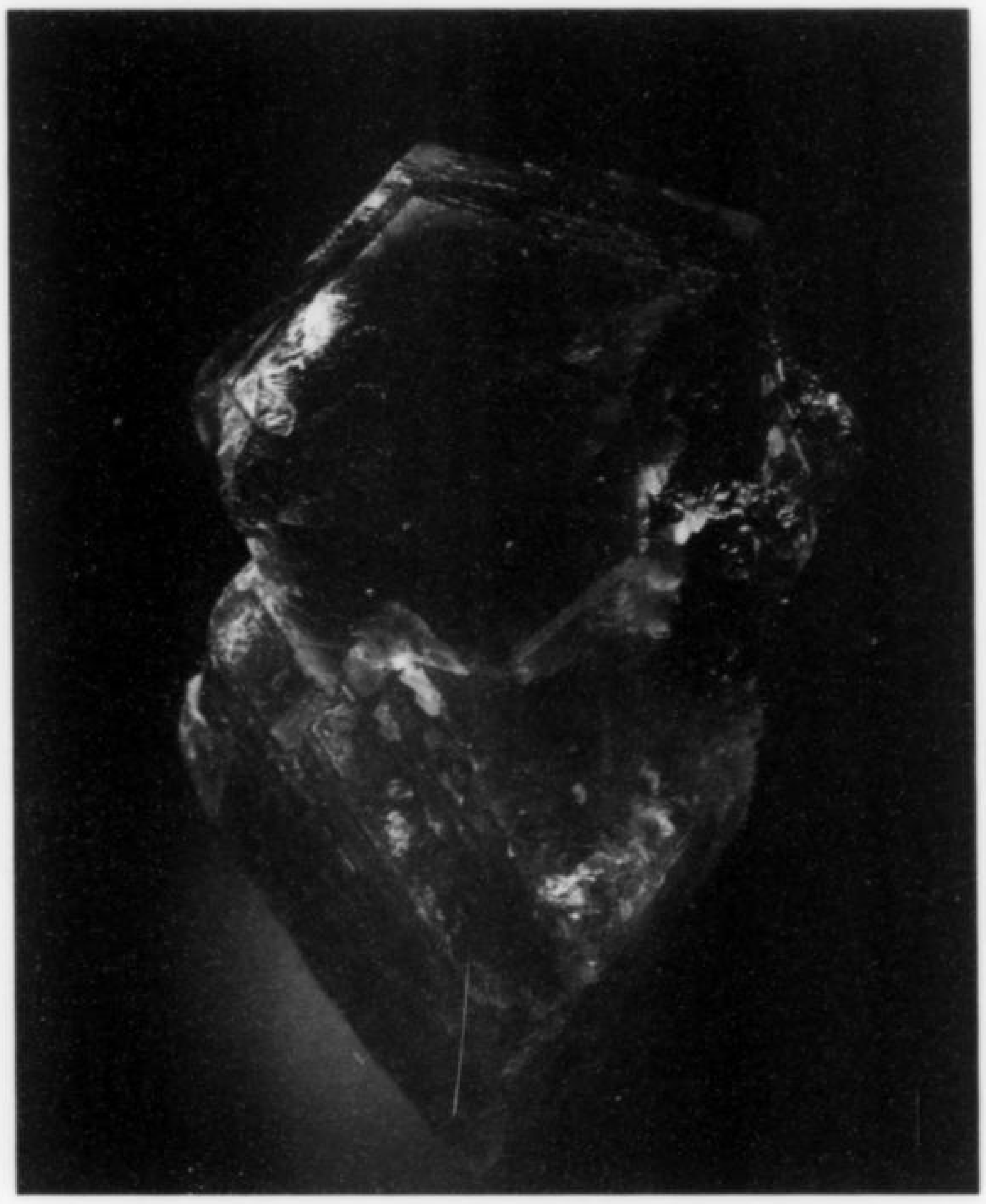


Figure 72. **Fluorite dodecahedron on rhodochrosite, Main Stope, 3.2 cm. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

On Saturday morning of the Denver Show, Dave Wilber invites an elderly couple to Bryan's 11:00 a.m. talk on the Sweet Home. They sit in the front row and listen intently. An hour later, Dave tells Bryan that the couple, Mr. and Mrs. Richard Rice, are interested in buying the Rose. Bryan doesn't want to split up the pair and quotes a combined price for both. On Sunday morning, the Rices agree to buy the pair.

Bryan Lees:

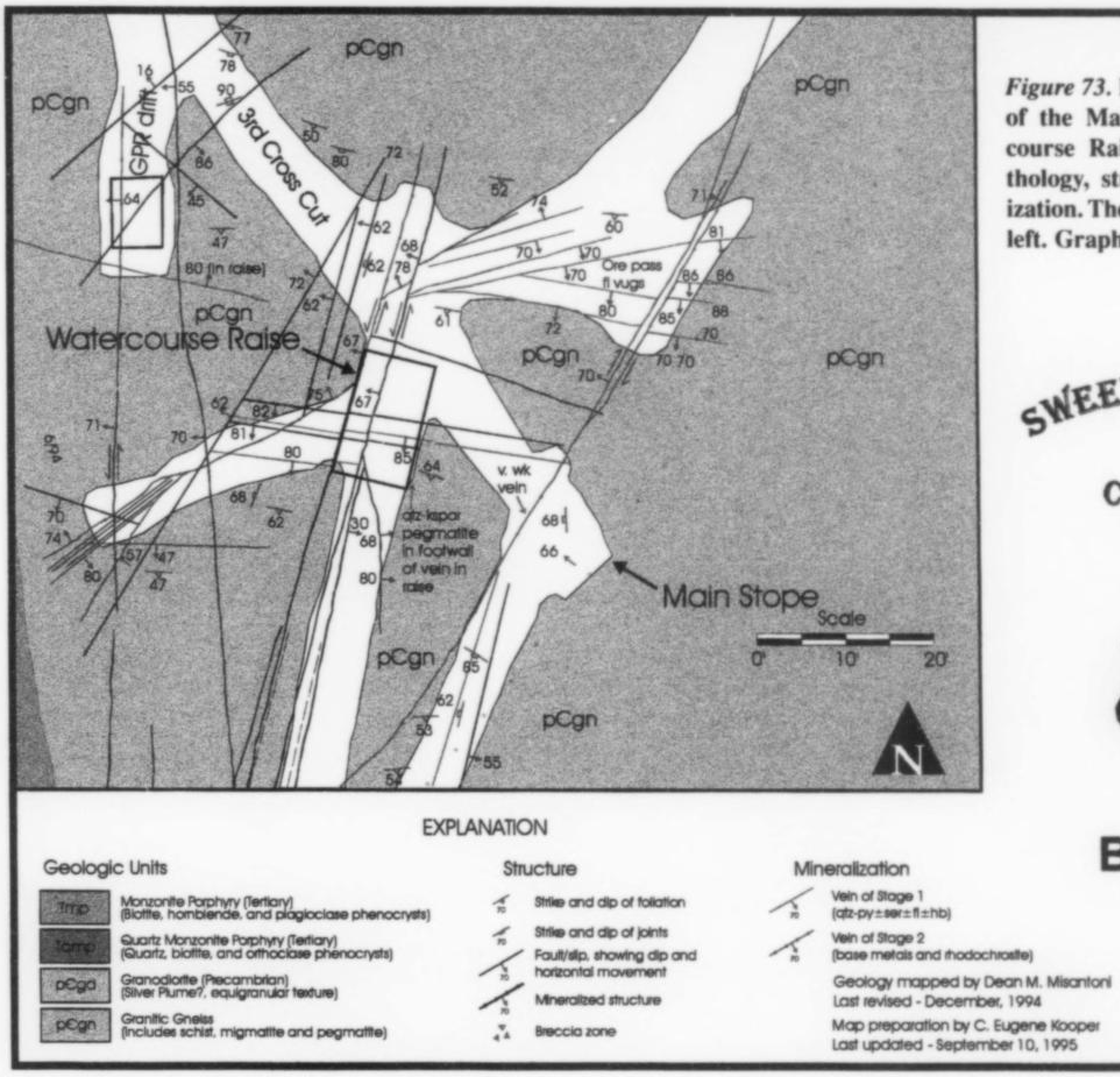


***Figure 73.* Detailed geologic map of the Main Stope and Watercourse Raise areas showing lithology, structure and mineralization. The GPR drift is in upper left. Graphics by Bill Tanaka.**

SWEET HOME MINE
ALMA
COLORADO

BOX "B"

The Rices' decision lifted a great weight from the shoulders of the company. The sale validated both the quality and the price of the specimens and renewed our belief that we had a truly world-class specimen mine. Also, we would now have the operating funds to run the mine another year. This was the project's biggest day since the original discovery of the Rainbow Pocket. After the Rice sale, our other top pieces began to sell more quickly too.

Meanwhile, at the mine, 75 feet up in the Tetrahedrite Stope, Scott opens a pocket full of what's probably the best hübnerite ever seen in Colorado. Unfortunately, the Hübnerite Pocket is tight and most of the pieces are damaged.

September 21–25: About 20 tour groups visit the mine. Scott pushes onward from the Hübnerite Pocket and hits another vug full of wonderful plates of pyrite crystals on needle quartz—the Pyrite Pocket. Rory begins a new drift, aiming for a GPR target. This would become the GPR Drift.

Bryan Lees:

Anyone who believes that rhodochrosite mining is easy should have been working at the Sweet Home in 1993. We decided to follow the vertical structures above both the Rainbow and Good Luck pockets—that meant two straight-up stopes. We were having a hard time finding qualified miners, so we drove the raises with only three people—Rory, Scott and myself. Carrie handled the duties of portal watch and emergency surface person as she had in 1992.

By late summer, the raises were each up about 100 feet and very little had been found. At 11,600 feet above sea level, climbing up and down the ladders several times a day carrying heavy equipment made the mining task almost unbearable. We had reached the limits of our resources. Everybody was tired, beat-up and fed up. We all decided to pull back down to the main track level and begin some horizontal drift work into new areas. Before we could ever go back up into the raises, we would have to install hoists to lift the heavy equipment, followed by some serious timbering work. This was not to happen for two years.

September 28–October 5: In the GPR Drift, halfway between the Main Stope and Tetrahedrite Drift, Rory hits three pockets all about where the ground penetrating radar had predicted. From one comes a beautiful 1½-inch purple stepped-face octahedral fluorite with no damage. Bryan decides to call this vug system the Blueberry Pocket (see "Application of Ground Penetrating Radar to Mineral Specimen Mining," this issue).

In the Tetrahedrite Stope, Bryan takes three days to open a 50 x 30 x 4-inch vug called the Empty Pocket. It has very little rhodochrosite (even though it's on the same vein intersection as the Rainbow Pocket, 70 feet higher) but contains fine specimens of associated minerals.

October 6: Vugs are hit in both the GPR Drift and Tetrahedrite Stope.

October 8: In the GPR Drift, splitting a vug reveals some fine

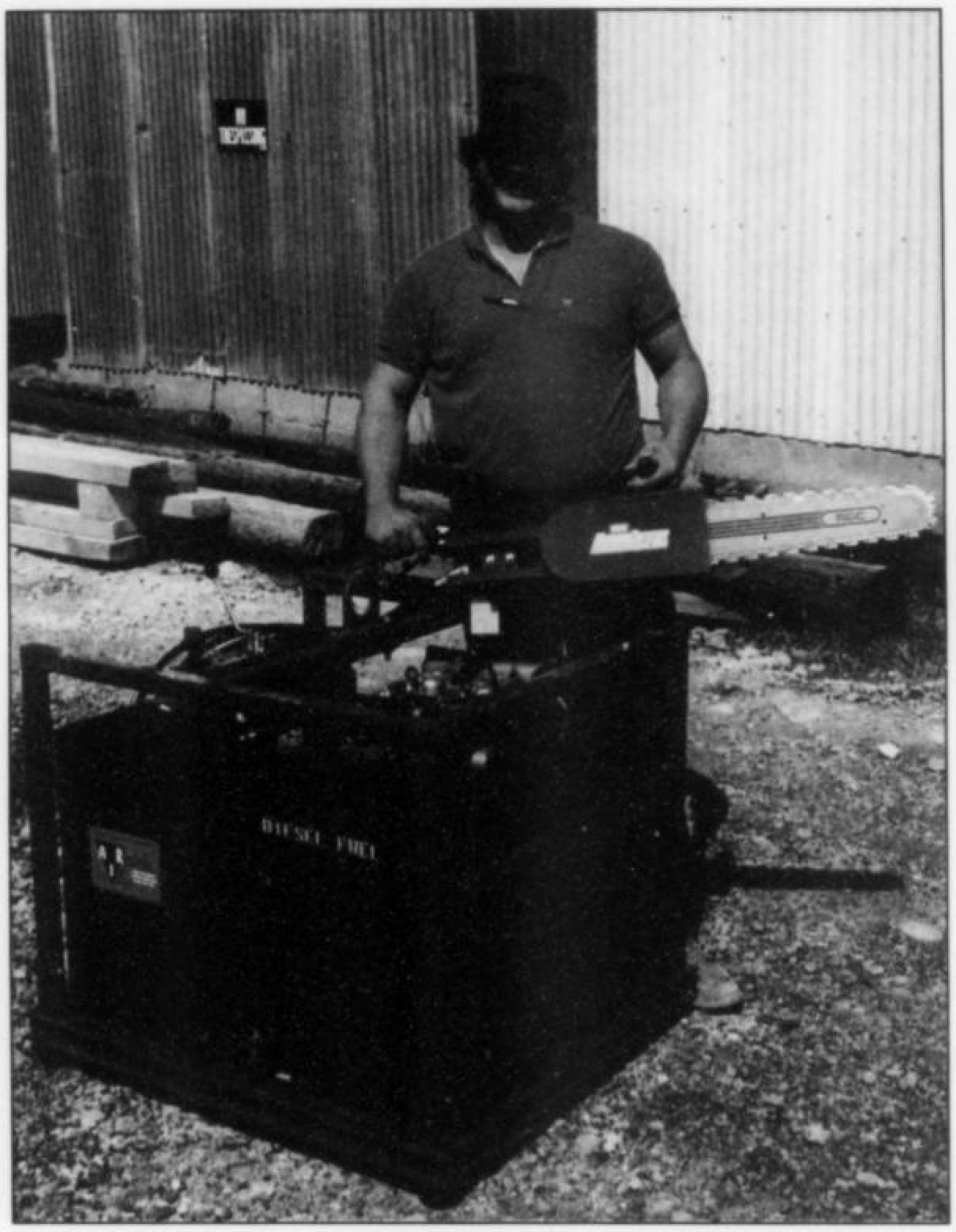


Figure 75. **Rory McDonald after finishing drilling a raise (straight up) in the Main Stope. The expression on his face mirrors the kind of year it has been at the mine and shows the general mood in September 1993. Photo by Bryan Lees.**

Figure 74. **Roger Stiner displays the Sweet Home mine's new diamond chainsaw. Due to this recently developed device, many great rhodochrosite specimens are being preserved. Photo by Bryan Lees.**

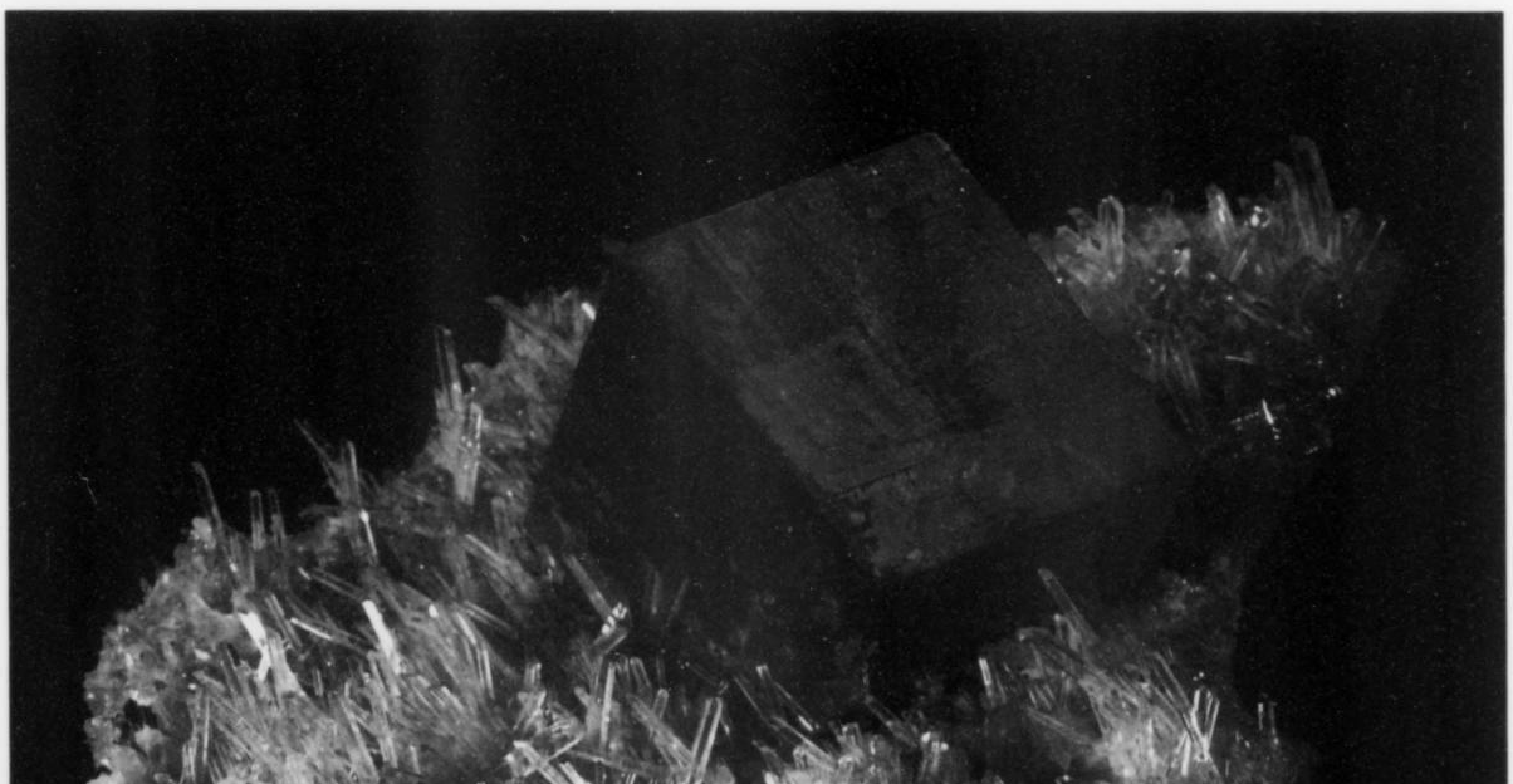


Figure 76. **Rhodochrosite on quartz, Blueberry Pocket, GPR Drift, 10 cm. Gene Meieran collection; photo by Harold and Erica Van Pelt.**

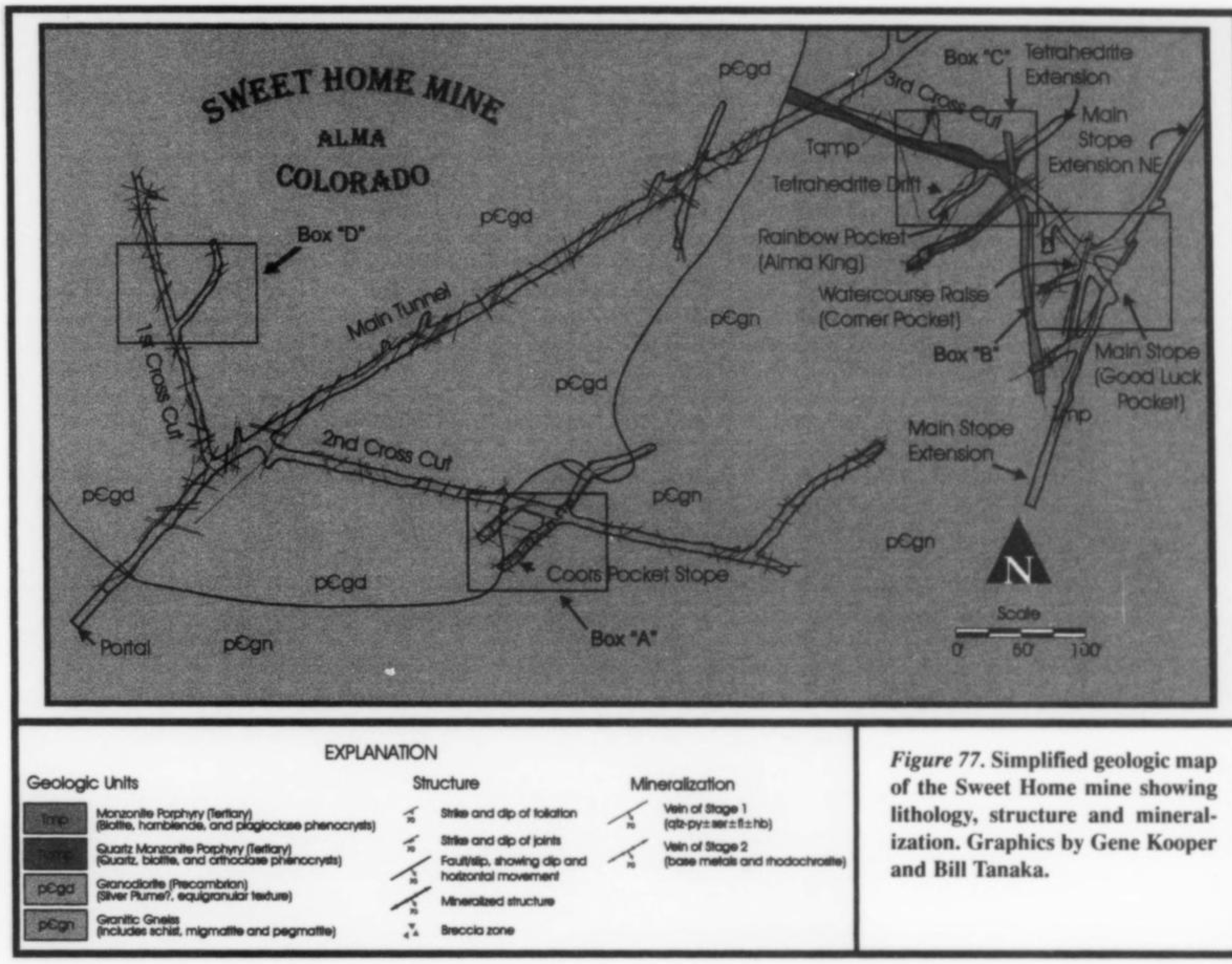


***Figure 77.* Simplified geologic map of the Sweet Home mine showing lithology, structure and mineralization. Graphics by Gene Kooper and Bill Tanaka.**

rhodochrosite, notably a gemmy, loose 1½-inch rhomb sprinkled with small gemmy fluorites (it will later be restored to its matrix).

October 9: In the GPR Drift, the upper part of the Blueberry Pocket pinches out but there's an unexpected upper chamber beyond. This yields some excellent thumbnail and miniature rhodochrosite specimens—gemmy and unetched, some on matrix, with good quartz crystals.

October 10: In the GPR Drift, they finally use a newly developed diamond chain saw (Fig. 74): "It's very slow, wet, miserable work. The [Blueberry] pocket is above our heads so we get soaked with the cold, muddy mine water lubricating the saw." After six hours of this, they have sliced off the matrix for some killer rhodochrosite rhombs pulled out the day before—Bryan expects that these last Blueberry Pocket specimens, when repaired, will be the '93 season's best pieces. All told, three good pieces are removed.

October 11–November 11: Rory and Carrie move to Butte, Montana. A further 30-foot raise over the Blueberry Pocket reveals nothing.

In a new area near the original watercourse vein, Scott begins the Watercourse Extension Drift. Only one area looks good along this new course, and a 20-foot raise produces a 6-inch vug which contains a few very good rhodochrosite miniatures. They will take up here again next season.

Bryan Lees:

It was obvious to us at the end of 1993 that we had not figured out the entire geological puzzle. We knew that pockets occurred inside vein intersections but, unfortunately, that did not mean the entire intersection would have pockets. We speculated that there must be another control we hadn't yet figured out. Our hope was that eventually, if we raised high enough on the intersections, we would find a favorable control and come into a new pocket zone. But to raise high enough would require more equipment, money and manpower. That didn't happen until 1995.

THE 1994 SEASON

The 1994 mining season would prove to be much more fruitful than 1993. If not quite up to 1992, it was good enough to keep all hands enthusiastically going and Sweet Home Rhodo, Inc. solvent into 1995. Its major excitements, in the forms of the Tight, Corner and Coors Pockets, did not begin to materialize until late summer.

The season's first half was more than a little discouraging. Journal entries for May through mid-August, therefore, tend to be generalized, biting off whole, relatively barren weeks at a time. (Here, the gap will be partially filled by observations from my visit during that August of '94.)

The "Watercourse Extension Drift," where Scott began working at the very end of the '93 season, evolved into a complex series of raises; the journal generally calls this vertiginous region of upward burrowing the Watercourse Raise. Its maze of platform above platform, with shaky ladders rising at all angles, would finally produce the Tight Pocket and Corner Pocket complexes. But in Crosscut No. 2, near the pocket finds of the 1920's, would be

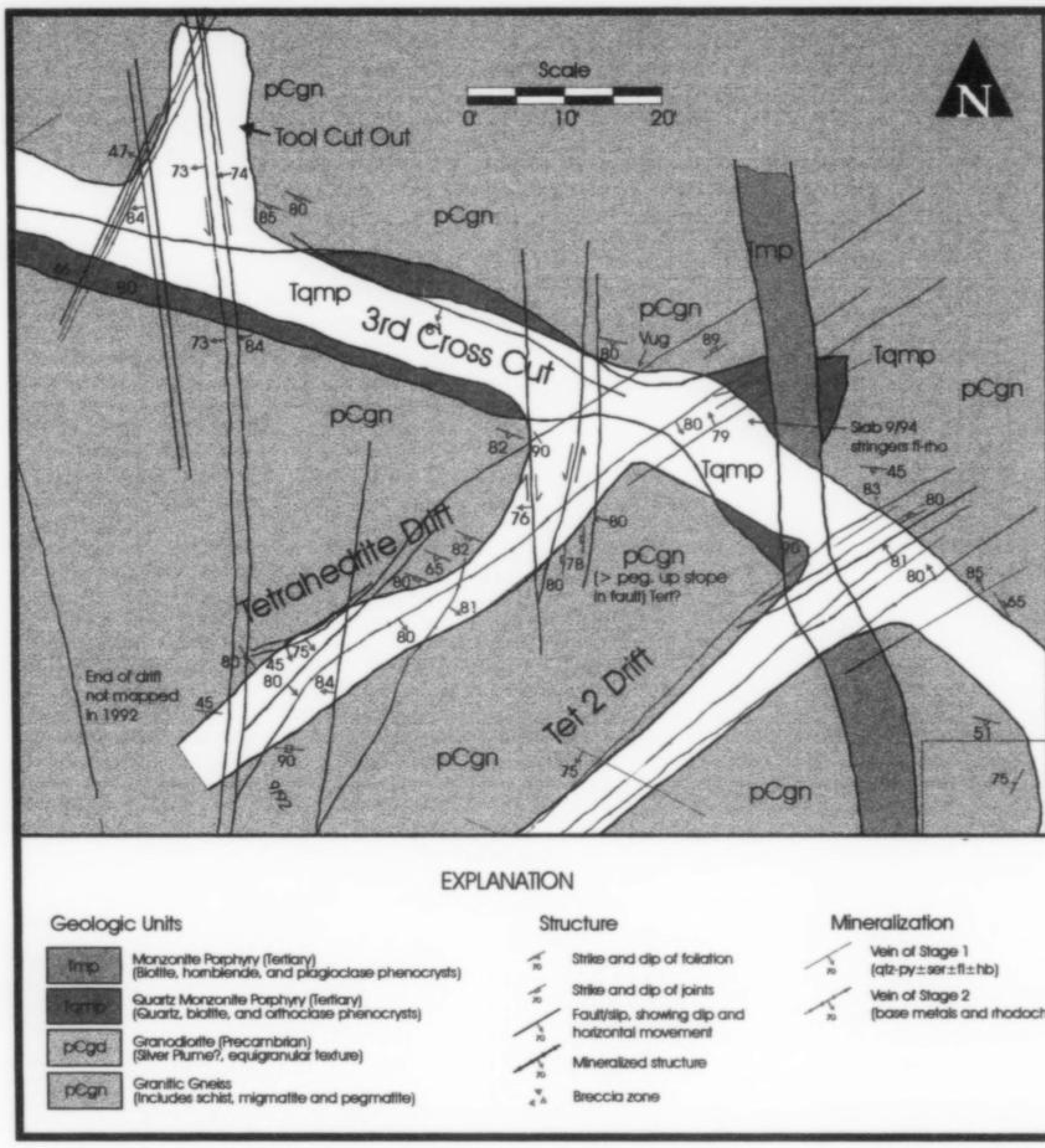


Figure 78. **Detailed geologic map of the Tetrahedrite Drift area, showing lithology, structure and mineralization. Graphics by Bill Tanaka.**

SWEET HOME MINE

ALMA

COLORADO

BOX "C"

1994's most spectacular find: the Coors Pocket, so named because of its reconstruction and permanent display in the Coors Hall of Minerals at the Denver Museum of Natural History.

May 18–31: They'd wanted to start the season with three miners and a support person, but on opening day only Scott shows up. Bill Kazel brings in a helper and Dean Misantoni is hired full-time as mine geologist.

They re-open the old Corkscrew Adit high above the portal and Dean maps the old workings. It is just a mined-out area in a decomposed gouge-type ore zone with no rhodochrosite showing. They will re-cave it probably.

On May 31, after taking out the first round to extend the watercourse on a new drift, Scott hits a pocket, later called the Memorial Day Pocket. It yields a banana box full of specimens with slightly dull rhodochrosite rhombs to 5/8 inch on quartz needles.

June 1–7: Scott continues the new drift but there is no more good structure and no new pockets. On June 7, he stops. They're having a hard time finding qualified hands to replace the no-shows.

Bryan Lees:

> With no significant finds in '93, there were some tense periods in early '94. We'd gone almost two years without an important discovery. Funds, nerves and tempers were running thin and thoughts of mine closure were once again being explored by the company.

June 8–20: Scott starts the "Tet-2" drift or New Tetrahedrite Drift, a structure parallel to the original Tetrahedrite Drift. The hope is to intersect the north-south faults that created the Colorado Springs and Rainbow pockets in the Tetrahedrite Drift.

Roy Rizzardi and Mike Warren team up to fix equipment, dispose of muck in the second crosscut and prepare to continue the raise in Scott's '93 target area in the Main Stope.

June 20–July 10: They hire a new raise miner, Dan Stephens, from the Smuggler mine project in Aspen. Mike and Dan begin raising upward along Scott's heading in the Watercourse Extension Drift. Robin Theobold tours the mine on June 20.

On July 1, a nice fluorite/rhodochrosite miniature rolls out of a drill hole in the raise at the end of the Watercourse Extension but the indications generally don't look good. The raise is abandoned on July 10.

Scott pushes the New Tetrahedrite Drift but the mineralization is "lousy." Dean Misantoni is "mapping the daylights out of things and handling the portal watch. I think he hates portal watch." Bill Kazel can't seem to get good drill steel or bits. The steels are breaking in half and the bits are blowing up. In the past month, they've gone through $2,500 in steel.

July 11–26: In the Watercourse Extension, Mike and Dan begin another new raise. There's a 3-way vein intersection here that looks very good. By July 26, they are 28 feet up on the raise. Bryan writes:

> Anxiety now rules. Without a good find for almost two years, I find myself more on edge than usual. . . . I hoped with Dean here this year we would have two heads working on the rhodochrosite puzzle . . . but it seems that we just have more puzzled people.

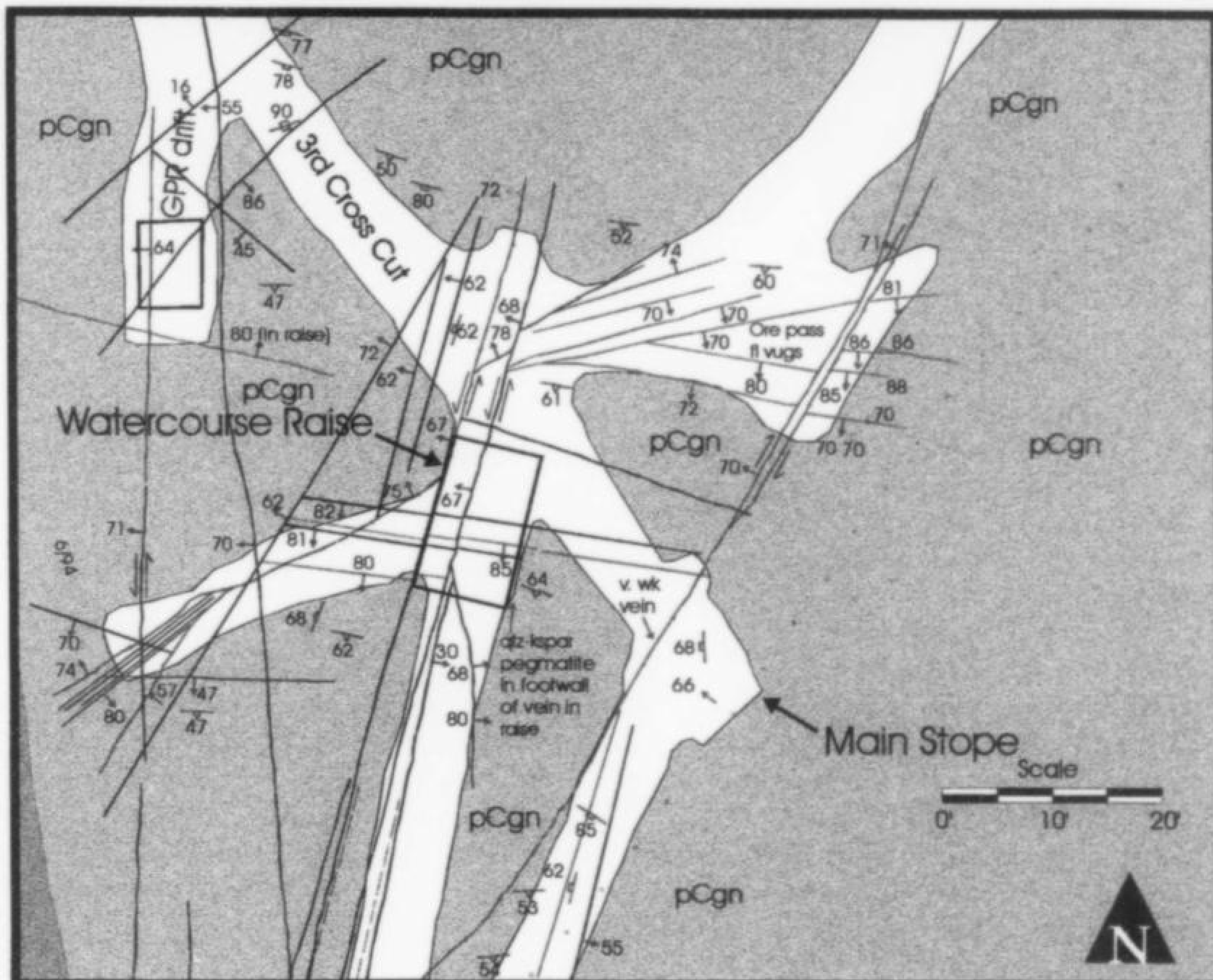


***Figure 79.* Detailed geologic map of the Main Stope and Watercourse Raise areas showing lithology, structure and mineralization. Graphics by Bill Tanaka.**

SWEET HOME MINE
ALMA
COLORADO

BOX "B"

July 27–August 20: Dan and Mike take the Watercourse Extension raise up about 50 feet with almost no rhodochrosite to show for it. On August 4, they abandon the raise and move on to another target directly above Scott's Memorial Day Pocket. This will become known as the Watercourse Raise.

On August 6, five feet above the Memorial Day Pocket, Dan and Mike hit a nice, new 20 x 15 x 2-inch pocket containing about six good rhodochrosite plates. On the next raise round, the pocket continues and specimen quality improves. The plates average 2 x 3 inches with rhodochrosites sitting up well on quartz matrix—very aesthetic. The material from the Tight Pocket, so named because it's so narrow, somewhat resembles the Cash Flow Pocket material, but the rhodochrosite luster and crystal sizes are better. It takes four days to collect. Pat Haynes comes up to lend a hand on August 10 and 11. On August 12, Dan and Mike continue up the Watercourse Raise from the Tight Pocket for two more rounds with no results. My first visit is during this time, to begin work on the *Mineralogical Record* article.

For four days the crew at the Sweet Home mine suffered me to get in the way and look around. Bryan took me for a quick stop in the Golden shop, but then we hurried on to the mine. I wanted most of all to be on hand and underground when a major pocket was struck. Luckless in this regard, I nevertheless consider myself one lucky Visiting Eastern Dude just to have had these few days—to have gotten a whiff of the hunt.

A mustard-yellow cinder-block building on the outskirts of Golden is the home of *Collector's Edge.* Rhodochrosite-studded quartz plates from the Tight Pocket were spread out on a table awaiting attention. Great indeed was the contrast between what they looked like now (a wan pinkness just showing through the mine dirt and chalk-like silica lint) and how I knew they would look in just a few days. The shop was full, in fact, of fine prepped specimens, lying around among the big machines, the crates and the tiers of metal shelving, the flats and the chemical vats. Over there, for example, was the enormous rhodochrosite/tetrahedrite specimen from the Good Luck Pocket (see "What's New in Minerals?" vol. 26, no. 2, p. 153) reclining regally on a blue blanket atop a filing cabinet.

On a desktop was something deserving of a digression here—a large, brown, empty beer bottle, its label showing a colored sketch of a fine rhodochrosite/quartz specimen of obvious Sweet Home origin. Above the sketch appeared the words "Sweet Home Lager." It seems that Bernie Kowalski, an avid beer and wine maker by avocation, took a tour of the Sweet Home in 1992 and got a fruitful idea. "Let's make some beer and store it in here!" The temperature in the mine is a constant year-round 48 degrees F, similar to the temperature at which German brewers age their best Lagers. The 45 bottles were aged in an unused stope for two months. It was during that time that the grafitto "Sweet Home Lager" appeared in white paint on the rusty brown water tank beside the mine portal. Bottles of Sweet Home Lager are given to special "Sweet Home friends." There is no commercial marketing, and when the mine closes, so will end the production of this tasty brew.

During the shop tour, a nervous phone call came in from Bill Kazel, the Sweet Home mine manager. During the previous night, when lightning strikes had been thick in the mountains as they often are in the summer, one bolt had hit the Sweet Home semi-trailer, putting the air compressor out of commission and frying a lot of wires. They were lucky, Bill said, that no fire ignited in the mine. We would be arriving tomorrow at a quiet mine, as no underground work was planned, pending repairs to the support equipment.

So . . . an overcast, cool summer morning . . . a lightly trafficked road going west into the Rockies' Front Range . . . folded synclines, crags, evergreen forests, old mine buildings and mine-tailing piles and waste flats around every turn . . . and finally the "city" of Fairplay. This is about a mile's worth of tourist shops, gas stations, grocery stores, residences and, of course, the Fairplay Hotel (where the miners go in the evenings for sustenance) all strung out by the roadside. Five miles further along the highway, on the western edge of the similar-looking but even smaller town of Alma, appeared the road to the mine—a pitching, rutted and sharp-toothed dirt track that hugs the trout stream flowing down Buckskin Gulch. The mountains ahead showed remnant snowfields at high altitudes, and bare-brown, solemn Mount Democrat scree with snow patches hard by the sky.

The mine lies 4 miles up this road from Alma. The road proceeds a mile still further up to glacial Kite Lake, on whose shores is a Pike National Forest parking lot. Thus, caravans of vans and campers kept lurching past the mine site all day, and spots of plastic-tent colors could be seen down in the flat places along the stream. Watching these caravans bounce past, the miners would sometimes shake their heads slowly, faces registering combinations of amusement, rue and contempt. The main cultural conflict in these parts seems to be between locals, most of them miners and/or serious sport hunters, and carpetbaggers of various kinds. Over an Alma grocery store's front counter is a sign with the words "Politicians Like Gun Control," framed by a swastika and a hammer-and-sickle. But Nature up here, all the while, remains of an apolitically marvelous beauty. Along the road to the lake, the secretive landscape dreams itself all around, from the ruminative rushing stream at one's feet all the way out to impossible heights where hawks glide across the sky.

The mine site consists of a widening in the road, a waste dump, a graveled bed for the semi-trailer, a containment-pond area, a modest wooden headquarters building, a Port-o-Potty, and, at the base of a very steep hillside, the lone mine portal. The miners, veterans of much serious work in huge ore deposits, call this, affectionately, a "piddly little mine." But, as in any mine, anyone going in must wear a cumbersome outfit—heavy rubber boots, yellow waterproof body suit, hardhat with lamp (the battery for the lamp strapped to a heavy belt) and a small metal gadget called a "self-rescuer." The novice who wears all this feels amazingly obese and clumsy and, probably, when it comes time to climb steep ladders into narrow raises, not a little fearful.

On several occasions I got to watch how Dean Misantoni goes about hosting tour groups. About 20 people arrive, and Dean supervises their awkward suiting-up to go in groups of five into the mine, where they get a good walking tour of what's geologically and mineralogically interesting. In promising areas, it is easy enough to follow the courses of mineralized veins and to appreciate, with a sort of dumb hunger, the tiny pockets where needle quartz linings, fluorite and pyrite crystals frozen in brecciated zones, and massive rhodochrosite showings, come up in the beams of the lamps. The tour passes the sites of the big pockets, and it is strange to know that in just those black, empty spaces of air the Cash Flow, Rainbow and Good Luck bonanzas once rested. When a group comes out after an hour or so, its members have clearly learned much, and can't stop asking follow-up questions. Such tours go on all the time. They serve important purposes both educational and public-relational, and are respected by all mine hands.

The thrill of the search for specimens seems to have taken over the miners, none of them personally mineral collectors and none of them having any previous work experience in strictly-specimen mines. Their shop talk is full of casual allusions to "giant rhombs" and "good groups," even "sexy aesthetics." Scott says that the Sweet Home is a "miner's dream" precisely because collecting crystallized pockets is its whole point. Bill Kazel:

> It was hard at first to re-train these guys from the "blow-and-go" style of mining they'd been used to in the ore mines where the more you blast and the more rock you move in the shortest time, the better. Then, for awhile, there was some over-reacting the other way. They'd get paranoid and never want to shoot for fear of smashing every pocket from here to Alma, but experience gets passed along and dug-in. We've had crew changes but right now these guys know what they're doing, all right.

Early on my first morning at the Sweet Home, I went in with Mike and Dan, who were taking in timbers for building a working platform 25 feet up in the Watercourse Raise. It took them a while to haul these massive planks up on a rope, the slimy gray things bumping up along a slimy gray ladder. They hauled up the drill at last, and, following the vein structure, made about ten 5-foot-deep holes, being careful about the angles so as eventually to place the explosive charges just right along the vein. This was an area of intersection of two major faults. A seam of quartz/sulfides/rhodochrosite was clearly visible, arcing over the whole working face from one side of the raise to the other. Inch-thick showings of massive bright pink rhodochrosite and a couple of small pockets of needle quartz (one with a purple fluorite cube) were looking plainly at us. At a point where the seam was thickest, it "flexed" by about 30 degrees. Such vein flexures at fault intersections are, as the journal notes, usually good signs. While drilling, the miners remained alert, in their arms and nerves, for the tiny catches, buckings and leaps of the drill bit that might indicate a pocket boundary zone ahead. If one occurred, the man with the drill would have to withdraw it at once.

Work broke off when Scott came by to warn us that he was about to set off a shot in another part of the mine. While having lunch in the mine building, we heard the blast and felt the ground vibrate. Soon, the unpleasant clouds of black smoke were welling out of the portal. All hands would have to wait for at least another half hour before re-entering to see what the shot might have revealed, and before Dan and Mike, back at that promising raise, could finish their preparations for the next shot.

Maybe it was that blast or that evil black smoke, but what this day at the mine left me chiefly thinking about was how fundamentally scary is the environment of an underground mine, regardless of any and all engineering precautions taken to minimize specific dangers. The feeling is of the inhuman—that these depths neither "resent" our intrusion, nor "welcome" us, nor feel any "hostility" to us, nor anything of the anthropomorphic kind. The rocks are imbued with nothing at all but their own dumb weight; the crystallized pockets, having existed here for 30 million years, do not "welcome" the light we bring or our treasuring of them. The eeriness, even deathliness, we feel in mines is no matter of Earth Demons or other ancient icons of miners' superstitions. It is our own humanness folded back on itself, our own demon-whisper to the effect that these mute places do not "care" should we happen to miss what we seek in them, or even should they happen to crush us along our way. To return from underground to the biosphere of light and air, each time, is to feel something like relief, release, and

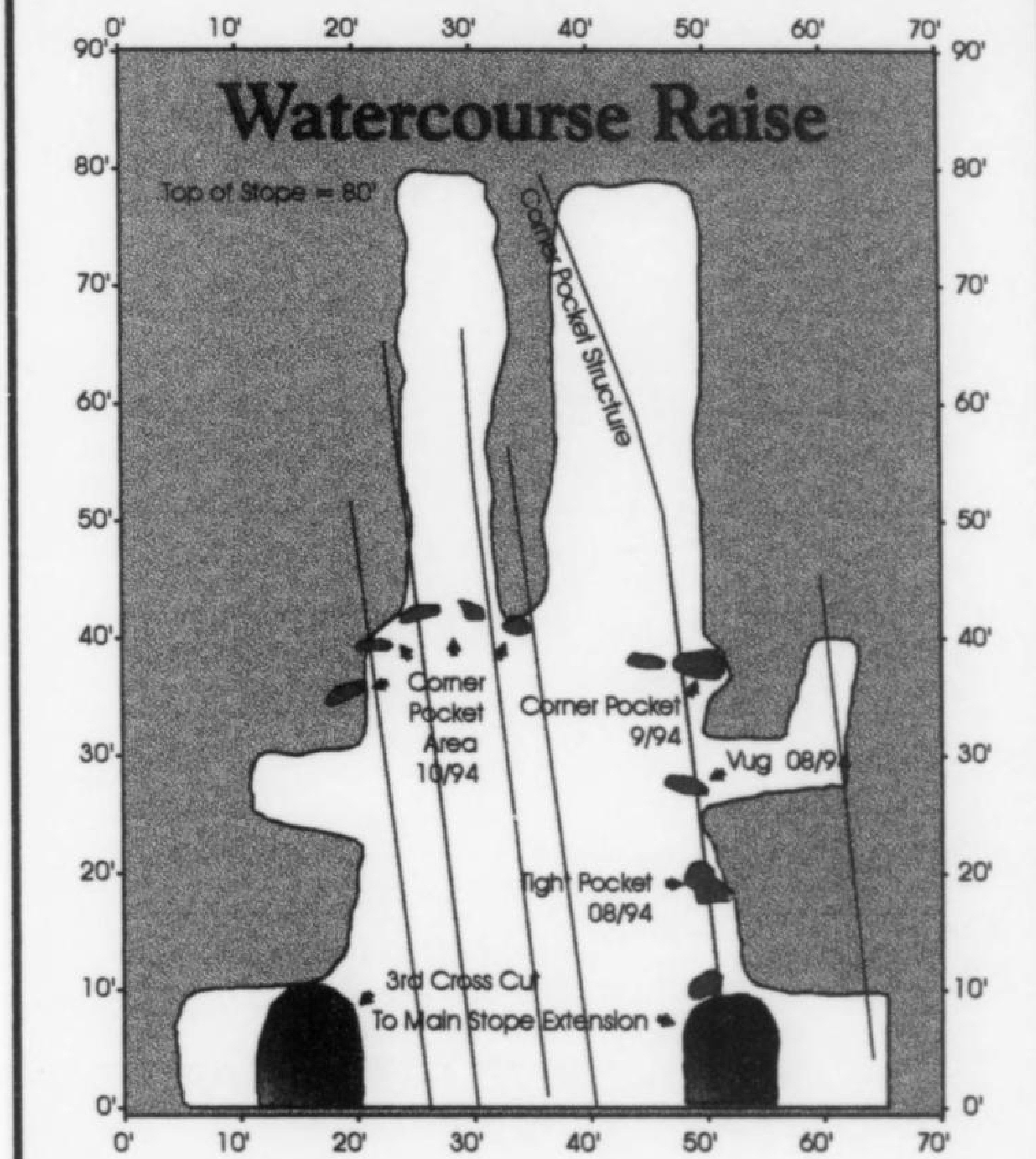
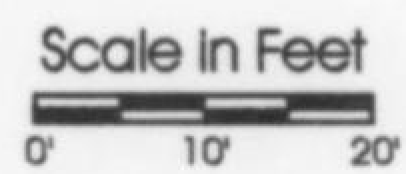


Figure 80. **Section of the Watercourse Raise looking east. Graphics by Bill Tanaka and Bryan Lees.**



life coming in again—even when no one happens to be around the portal and there's nothing to see but the green/brown ridge and blue sky over Buckskin Gulch.

In mid-afternoon of the next day, Mike and Dan were still at work drilling shot holes in the Watercourse Raise. Good technicians and eyeball geologists that all of these hardrock miners are, it is time to say something about what is even more important—their fortitude in accepting the endless unpleasantness of their daily work. Common sense tells us, but we should listen more often, that for every glamorous hour a miner spends collecting a crystallized pocket, even in a mine devoted to finding them, he spends something like 99 hours doing chores fully as unglamourous as their names: mucking, slushing, timbering, drilling, backfilling. Every pretty specimen in your display case is a product of some forever untellable number of man-hours of work that is physically grueling, dangerous, cold, wet and indescribably dirty. Those who complain reflexively about high prices on recently mined specimens might do well to consider these very hard facts.

In the raise, I watched, feeling mostly stupid and in the way and always a little uneasy for my safety, as these two men drilled shot hole after shot hole, heaving different lengths of drill shafts handily onto and off the jack-leg. This device made an incessant and terrible racket in that narrow space, and gray muck ran everywhere—down the walls and over us, covering our glasses until we couldn't see. Murky water sprayed our faces, rock dust fogged the air, timbers trembled under our feet, and still Mike and Dan paused sometimes to discuss and argue over wall structures that I couldn't even see anymore for all that streaming gray muck.

On the morning of the fourth day, they filled, at last, the 55 shot holes they'd made. First, the red-wrapped paper cylinders of dynamite went in, then the white coarsely powdered ammonium nitrate, and finally the brown paper plugs made by ripping up the nitrate sacks. Attached to each red cylinder and dangling down out of the holes, until the whole narrow raise was vermiformed with them, were yellow fuse wires. These Mike connected to a single red wire in a circle until an explosive chandelier floated ominously in mid-raise. They tore apart the timbered platform and heaved the boards, now coated inch-thick with gray muck, down to the main tunnel.

Outside, almost exactly at noon, we could hear the blast, one of the largest ever set off in the mine. A minute later, the now familiar black smoke billowed out. There was only just time, before I had to leave the mine site, to go back in to see the results of the blast. It was now or never for the Dude Pocket.

They were washing down the new face with a hose, both to look for pockets and to dislodge loose rock. I was not especially welcome now, as this is the most dangerous stage of the whole operation. A new muck pile is slippery, unstable, and no one knows which plate of newly loosened wall rock will choose which moment to fall onto whom. I aimed my lamp anxiously upward, seeing only its movie-projector-like dust-mote beam in the murk. From 25 feet above, where Dan and Mike were already up on a

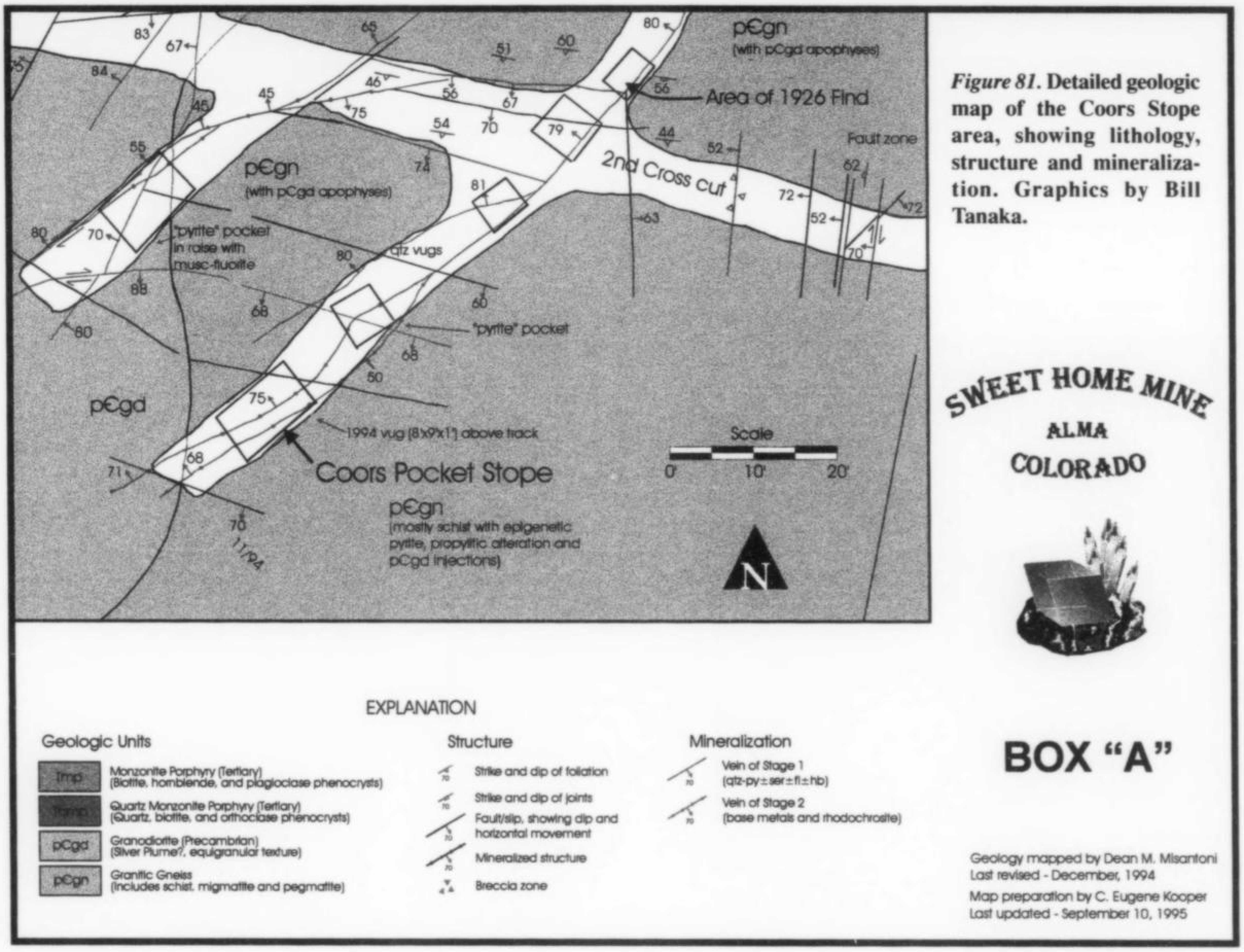


Figure 81. **Detailed geologic map of the Coors Stope area, showing lithology, structure and mineralization. Graphics by Bill Tanaka.**

crossbeam hosing the new face, no excited shouts of discovery came. Irrevocably, it was time to go outside, unsuit and catch my ride back to Golden.

August 23–31: Mike drills into a pocket on the left side of the Watercourse Raise. He shoots around it on the right. On August 31, they fan from left to right and drill into a beautiful small pocket up in the right corner. Thus, the discovery of the Corner Pocket, directly up from the Tight Pocket.

It's decided that Scott should abandon the New Tetrahedrite Drift and attack an entirely new target area in Crosscut No. 2, near the site of the 1925 finds (Fig. 81). There's a classic northeast-striking vein structure here but the whole area has been heavily altered to sericite and clay. Immediately in this new working, they intersect bad ground and need to chain and bolt the back for safety. Scott still is nervous so they abandon the small drift and start a new one 25 feet west and parallel. This new Crosscut No. 2 drift goes in about 30 feet. There are signs of rhodochrosite and pyrite but it doesn't look as good as the "bad ground" drift. They put in a couple of raise rounds anyway and hit some 2 x 3-inch pyrite cubes but no good rhodochrosite.

During August, exciting news rocks the Sweet Home project. Earlier in the year, the Rices had decided to let go of the Alma King specimen—returning it to *Collector's Edge* to re-sell. By late August, the Denver Museum of Natural History acquires the specimen. The news makes headlines in all of the local papers, on radio and television stations. Even *Newsweek* magazine prints a notice.

September 1–18: In Crosscut No. 2, they go back into the "bad ground" drift after all and take out a few more rounds. Miraculously, the ground firms up and additional bolting is not necessary. They are following a very highly altered, clay-filled, pyrite-enriched zone containing small grunged-up rhodochrosite. Dean is excited, liking what he sees in the geology.

On September 2, in the Watercourse Raise, Mike, Dan and Bryan open up the Corner Pocket complex and take out ten killer specimens—highly lustrous, gemmy rhodochrosite much like the Good Luck Pocket pieces, though smaller.

Bryan Lees:

> We pulled out hundreds of excellent thumbnail to miniature-sized rhodochrosite specimens. A few fine plates also came out. One, collected on September 19 after two weeks of careful diamond chainsaw cutting, was removed from the pocket wall, trimmed and displayed at the Tucson Show in February 1995. The piece represented most of the hanging wall side of the Corner Pocket (Fig. 89). This small area in the Watercourse Raise produced over a dozen small pockets. Although no large, major pockets were discovered, the production added up to considerable value and helped make up for a long dry spell.

On September 5, Bryan leaves the mine to prepare for the Denver Show. Dan and Mike continue drilling, sawing and splitting away at the Corner Pocket.

September 19–21: Bryan returns to the mine and sees the

WEDNESDAY

THE DENVER POST

August 31, 1994 — *Voice of the Rocky Mountain Empire* — Final Edition
35 / 50 cents in Designated Areas

Crystal search yields a gem

By Ann Schrader
Denver Post Medical/Science Writer

Fire from dozens of droplet-tipped mineral crystals shot back as Bryan Lees shone a small light inside a pocket in the Sweet Home Mine near Alma.

"It looked like Christmas in there. There was red, white, purple, green. It reminded me of all the presents under the tree when I was a kid," Lees said of its glow.

Lees knew immediately that his search for a world-class rhodochrosite crystal had ended in a 10,000-foot-high valley about 100 miles southwest of Denver. A translucent, blood-red "squashed square" of rhodochrosite — called the "Alma King" — was electrifying in its pristine condition.

The 6-inch-long, 5½-pound specimen — contrasting sharply with a 2-foot-long, 100-pound plate of white needle-quartz crystals where it grew about 30 million years ago — was bought by the Denver Museum of Natural History with an Adolph Coors Foundation grant. It will be placed on display Friday in a specially designed case. The display provides a new entrance to the Hall of Minerals, which was founded in 1979 by a Coors Foundation grant.

Museum geology curator Jack Murphy called it "the foremost mineral of its kind from Colorado and one of the world's great minerals. The fact that it was found so recently is truly amazing."

Rhodochrosite is a non-metallic manganese carbonate mineral found in some gold and silver ore-bearing veins. It has no commercial value, and often is discarded.

Murphy said small amounts of rhodochrosite have been found in Colorado, but the specimens are

The Denver Post / Glen Martin

GEM OF A CRYSTAL: Bryan Lees points out details of the rhodochrosite crystal that goes on display Friday at the Museum of Natural History. **STORY, 1B**

Alma King crystal was a rare find

small, pink and grungy. Lees hopes the public "gets the same charge" out of the gem-quality Alma King he did at first.

The perfectly formed crystal is estimated as being nearly twice as big as the next-largest rhodochrosite specimen, the Alma Queen, dug out of the Sweet Home Mine in 1966. The previous discovery prompted Lees and his wife, Kathryn, to put together a group of investors to look for more. Bryan and Kathryn both graduated from the Colorado School of Mines and are owners of the Golden-based Collector's Edge, which deals in quality minerals and offers refining services.

For two years, faults were traced and mineral veins chased in the ne'er-do-well silver mine. Founded in 1876, the mine "wasn't known for anything. It was really a lousy mine," Lees said. But the mine yielded interesting mineral crystals as early as 1890, with specimens sold through Tiffany's in New York and shown at the American Museum of Natural History.

Lees said it took three weeks to pry out the Alma King delicately after the discovery in August 1992, and another three months to prepare it. "It is amazing that we found it, that we could get it out and that we didn't blast it pieces," he said. The dynamite charge that revealed the Alma King came within 8 inches of destroying it.

The specimen then was bought by an Oregon collector who planned to sell it. Then the foundation stepped in. There also were overseas offers to buy it. Murphy is glad the Alma King remains here since it "reflects Colorado's rich mineral heritage."

Figure 82. **Rhodo fever hits Denver, August 31, 1994; article by Ann Schrader.**

footwall plate of the Corner Pocket sticking out of the wall like a 12 x 20-inch flag studded all over with gemmy rhombs (Fig. 94). Several visitors tour the mine and witness the removal of this beautiful piece (Fig. 89). While the others are working on extracting this "flag" (it eventually comes out in two pieces, while the pocket re-opens and goes back another 8 inches exposing more incredible rhodochrosites), Dean excitedly climbs up into the raise with news: the discovery of the Coors Pocket.

In Crosscut No. 2, another 20 feet along the "bad ground" drift, the same clay-filled gouge zone has kept showing up, pinching out, then re-opening, while the rhodochrosite rhombs have remained unattached and etched. Early on September 19, Dean insists on putting in one more round before abandoning Crosscut No. 2. At 1:00 p.m., the blast goes off. At 2:00 p.m., it's still too smoky to see anything. At 3:00 p.m., Dean visits Bryan in the Watercourse Raise to say that when he looked up at the new exposure of the gouge zone in Crosscut No. 2 a cascade of rhodochrosite rhombs and small plates hit him in the face. A 2-inch rhomb actually bounced off his nose. Dean Misantoni:

> Scott and I had been working that drift for weeks and Scott kept being the pessimist, wondering why we were bothering to keep blasting on back. But I thought that almost for sure there was stuff in there. So then that rhomb fell out and bounced off my nose. I guess it hurt Scott a little too. . . .

When Bryan gets there and peers up into the opening, he sees a large vug full of rhodochrosite matrix plates stacked like cordwood. "It looked as though one could touch the bottom plate and they would all whoosh right out."

By Wednesday, September 21, they're drilling split holes to make the pocket more accessible. It's so packed with plates that no one can see its top. Bryan returns to the shop on Thursday evening with eight boxes of material.

DENVER

Rocky Mountain News

August 31, 1994 | WEDNESDAY | 136th year, No. 131

Bryan Lees of Golden displays the Alma King, the world's largest rhodochrosite crystal. He unearthed the crystal at a mine near Alma in Park County. Lees calls it the "Mona Lisa of Minerals." The crystal will go on display Friday at the Denver Museum of Natural History.

Steve Groer/Rocky Mountain News

Golden man digs up rare specimen

King of crystals goes on display

By Berny Morson

Rocky Mountain News Staff Writer

Two years of digging and blasting at the played-out Sweet Home Mine in Park County turned up nothing but dirt for lifelong rockhound Bryan Lees.

Then, at 3 p.m. on Aug. 21, 1992, a blast uncovered a crevice 400 feet below Mount Bross.

"It looked like Christmas in there," Lee said Tuesday of his first glimpse inside the crevice. "There were blues and reds and yellows in there."

Lees had uncovered the world's largest rhodochrosite crystal — a hunk of red manganese carbonate the size of a brick. The blues and yellows came from calcite and fluoride crystals in the rocks surrounding the rhodochrosite.

The rhodocrosite crystal — dubbed the Alma King after a nearby town — goes on display Friday at the Denver Museum of Natural History. It will be seen surrounded by the quartz formation in which it grew some 30 million years ago when the Rocky Mountains were young.

The priceless crystal is "the finest mineral specimen ever donated to this institution," said Jack Murphy, the museum's geology curator. It was purchased by the Adolph Coors Foundation for an undisclosed sum.

Rhodocrosite has no commercial use, but is prized by collectors. Quarter-inch crystals are typical, and 1-and 2-inch crystals are considered "excellent," Murphy said. The Alma King measures 6½ inches diagonally.

Lees and his wife, Kathryn Lees, head the Collector's Edge, a mineral company.

The Golden couple, both graduates of the Colorado School of Mines, leased the Park County property because of old reports of rhodochrosite crystals. The mine was last worked for silver in 1966.

Ten workers toiled fruitlessly at the mine for two years before discovering the Alma King.

"We were pretty tired and we were running out of money," Bryan Lees said.

By coincidence, a team from the museum was on site, making a video about rock hounds, when the discovery came. The video will run beside the Alma King in the museum's geology area.

The Alma King was loose in the crevice. But the quartz in which the crystal had formed had to be slowly chiseled from the surrounding granite. The crystal separated from the quartz 8 million to 10 million years ago, Murphy said.

When the 100-pound quartz chunk finally came loose, it landed on three of Lees' fingers. He has scars, but the quartz was undamaged.

The Sweet Home may contain more crystals, Lees believes.

But he won't find them. Two years after uncovering the Alma King, Lees has unearthed nothing of value at the mine.

His firm will abandon the search when the weather gets cold, Lees said.

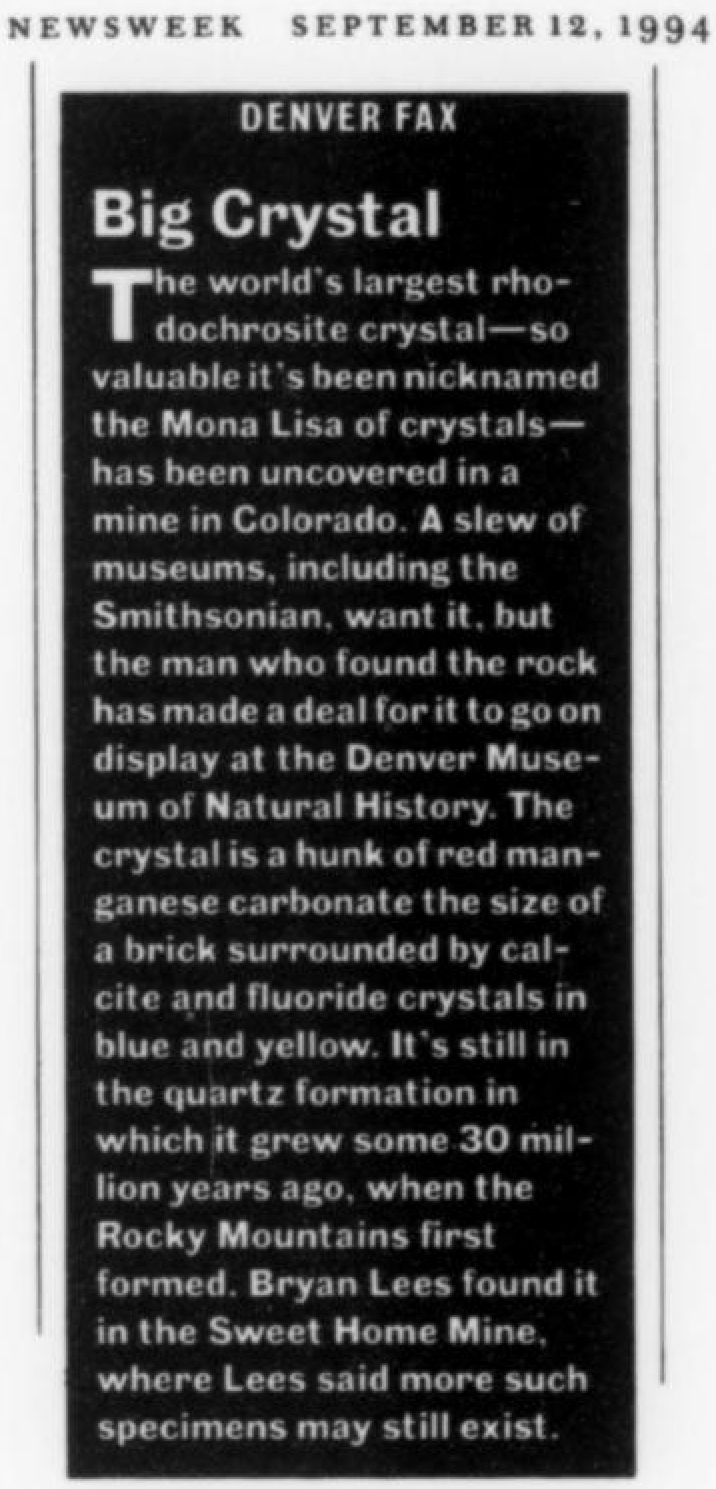
Figure 83. **Rhodo fever hits Denver, August 31, 1994; article by Berny Morson.**

Bryan Lees:

Upon a moment's reflection, I realized that we found the Coors Pocket the day after the Denver Show. Exactly two years earlier, the day after the '92 Denver Show, we hit the Good Luck Pocket. As improbable as it sounds, the day after the Denver Show has proven to be our good-luck day.

September 22: In the Watercourse Raise, Dan and Mike prepare a shot to make more room for collecting a new pocket next to the Corner Pocket.

In Crosscut No. 2, work on collecting the Coors Pocket gets seriously under way. Bryan sees that before splitting he'll have to remove some of the loose plates by hand. For about an hour, he pulls out one beautiful piece after another. The plates have



NEWSWEEK SEPTEMBER 12, 1994

DENVER FAX

Big Crystal

The world's largest rhodochrosite crystal—so valuable it's been nicknamed the Mona Lisa of crystals—has been uncovered in a mine in Colorado. A slew of museums, including the Smithsonian, want it, but the man who found the rock has made a deal for it to go on display at the Denver Museum of Natural History. The crystal is a hunk of red manganese carbonate the size of a brick surrounded by calcite and fluoride crystals in blue and yellow. It's still in the quartz formation in which it grew some 30 million years ago, when the Rocky Mountains first formed. Bryan Lees found it in the Sweet Home Mine, where Lees said more such specimens may still exist.

Figure 84. **Rhodo fever hits** ***Newsweek.***

Figure 85. **Mike Warren, Dan Stevens and Bryan Lees work overhead to remove a killer Corner Pocket piece. The extremely tight confines of the pocket make clean extractions very difficult. Photo by John Lucking.**

rhodochrosite rhombs to 2 inches sitting on matrixes of needle quartz, sphalerite and chalcopyrite. The plates, most having slightly separated from the vug walls, are easy to take out. Finally, one more major piece to pull out of the way remains . . .

When Bryan carefully nudges this plate, an entire section of the pocket gives way. Rhodochrosite rhombs, plates and debris rain onto his helmet as he tries to snatch the larger plates before they smash on something. He saves about six terrific specimens, one of them an 8-inch plate of 1 to 1½-inch rhombs in perfect condition. Some of the Coors Pocket specimens feature a quartz druse coating on two faces of the rhodochrosites. The coating is often brown from incipient iron staining. On top of the sphalerite base that composes each plate, there are often ¼-inch chalcopyrite crystals and the odd hübnerite crystal. There are abundant small, bent, solution-etched quartz crystals, looking like little upside-down icicles. "I can't wait to get back up to the mine next Monday."

September 26: In the Watercourse Raise, they re-timber a platform, look up and find that they have accidentally blown out half of the new pocket. Bryan does collect from it some nice lustrous loose rhodochrosite rhombs, some with quartz. The new raise face still looks interesting, with a 2-inch rhodochrosite seam in the middle.

In Crosscut No. 2, Scott and Bryan keep drilling and splitting the Coors Pocket. A real "grunt of a day" is rewarded with more superlative matrix plates of rhodochrosite with sphalerite, chalcopyrite and quartz. Bill and Carol Smith, George Robertson and Bill Hawes come up to see the pocket.

Mine Foreman Roy Rizzardi:

> Oh, man, there's nothing like seeing a pocket like that in place in the mine. Everything seems brighter in the lamps than it does when it gets outside in the sunlight. Maybe we ought to just leave it in there after all.

Figure 86. **Rhodochrosite on quartz, Corner Pocket, Watercourse Raise, 5.1 cm high. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

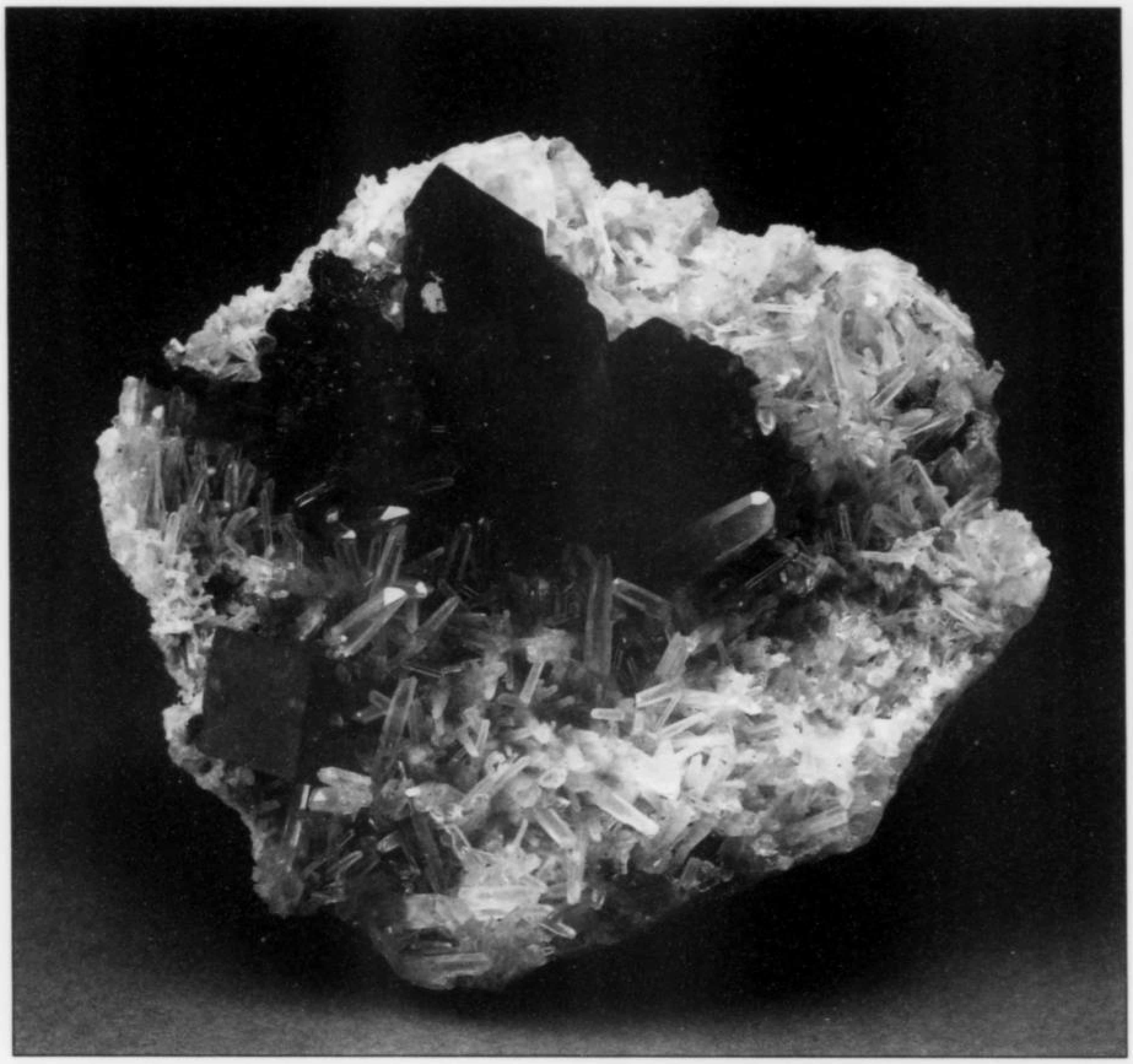


Figure 87. **Rhodochrosite on quartz with tetrahedrite, Corner Pocket, Watercourse Raise, 7.3 cm wide. Bob Johnson collection; photo by Geoffrey Wheeler.**

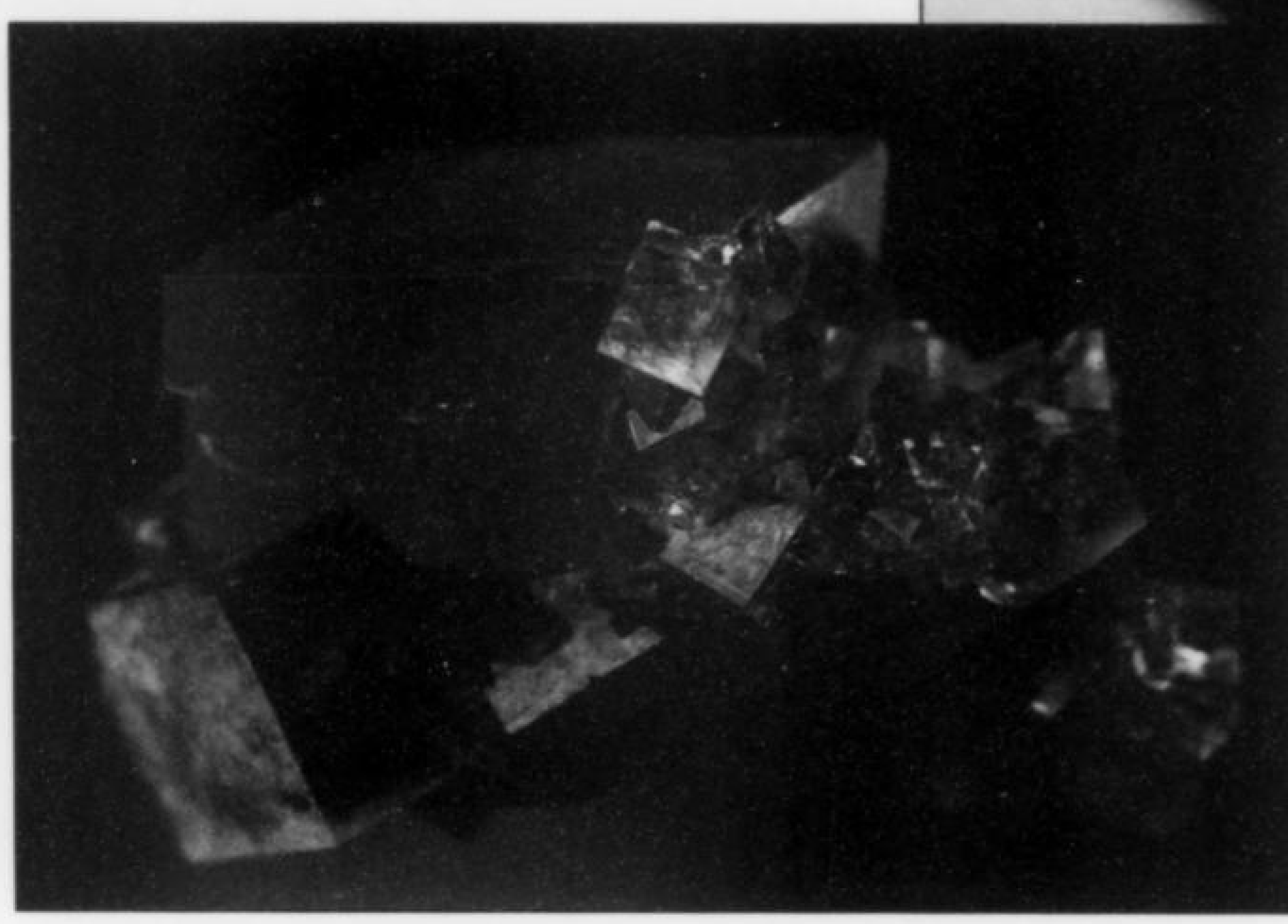


Figure 88. **Rhodochrosite with fluorite, Corner Pocket, Watercourse Raise, 2.2 cm. Although most are small, the specimens from this pocket are among the finest quality ever found at the Sweet Home mine. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

September 27: In Crosscut No. 2, extraction of Coors Pocket pieces continues. In the Watercourse Raise, Dan, Mike and Bryan hit an extension of the Corner Pocket. When Bryan leaves, he gives instructions to shoot into this.

September 29: A bad day and a good day. . . . In the Watercourse Raise, Mike and Dan's last shot blows up 80% of the visible pocket extension and Bryan is not pleased: "You can't shoot along sides of vugs! You must shoot perpendicular to the vug opening!"

Bryan Lees:

As every field collector knows, not damaging mineral pockets during the discovery process can be a difficult task. Slight misjudgments in pocket location, layout or contents can spell disaster. Such was the case on September 29. We just finished cleaning out the Corner Pocket and were drilling holes behind it looking for pocket extensions. Sure enough, 3 feet into the wall, we intersected another pocket. We decided to place a small blast to get us closer in. Unfortunately, that blast shook apart the hanging wall of the pocket. The pieces rattled around

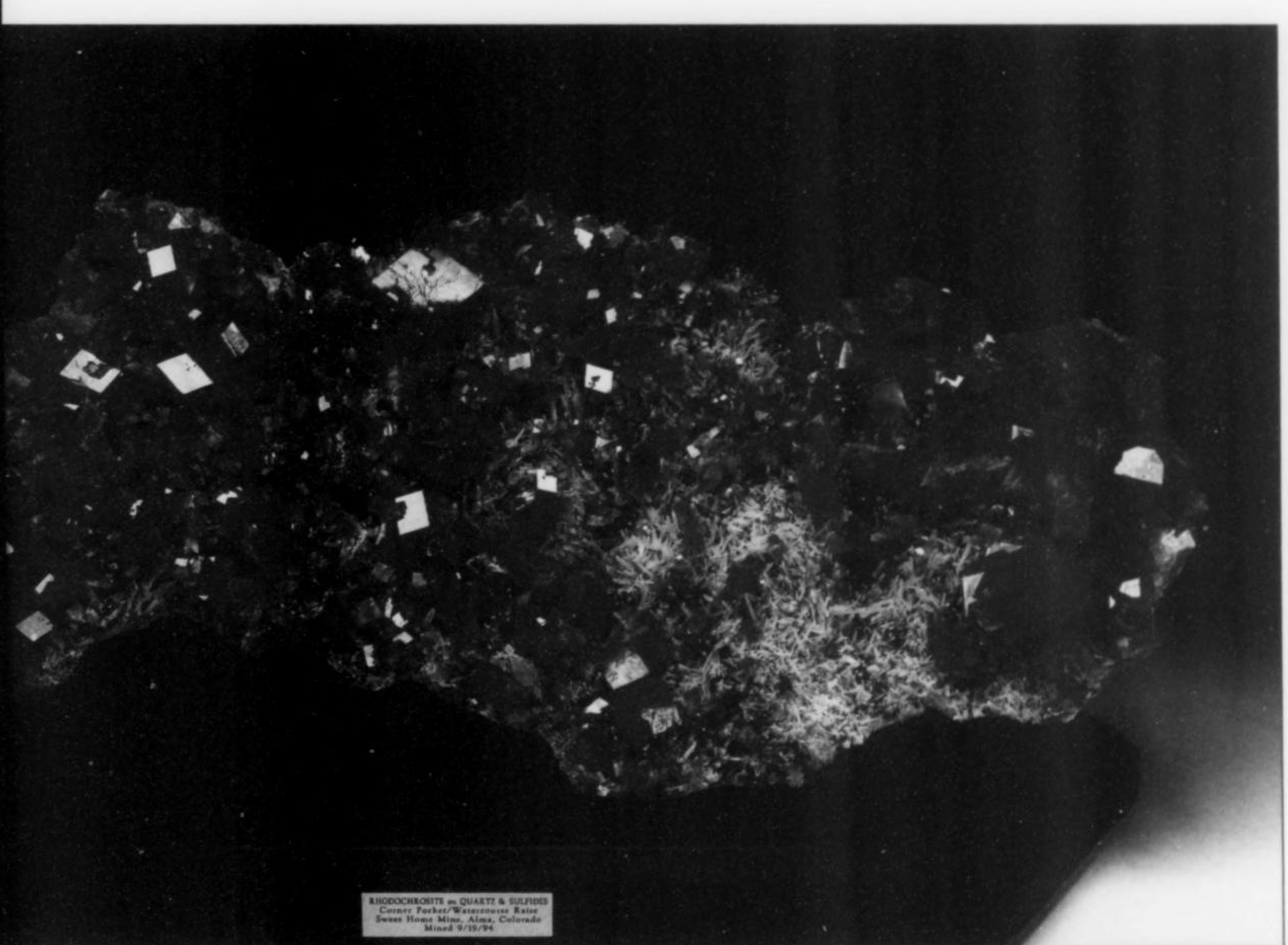


***Figure 89.* The footwall of the Corner Pocket. The plate measures 60.3 cm long. Removed intact, thanks in large part to the hydraulic splitter and diamond chainsaw. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

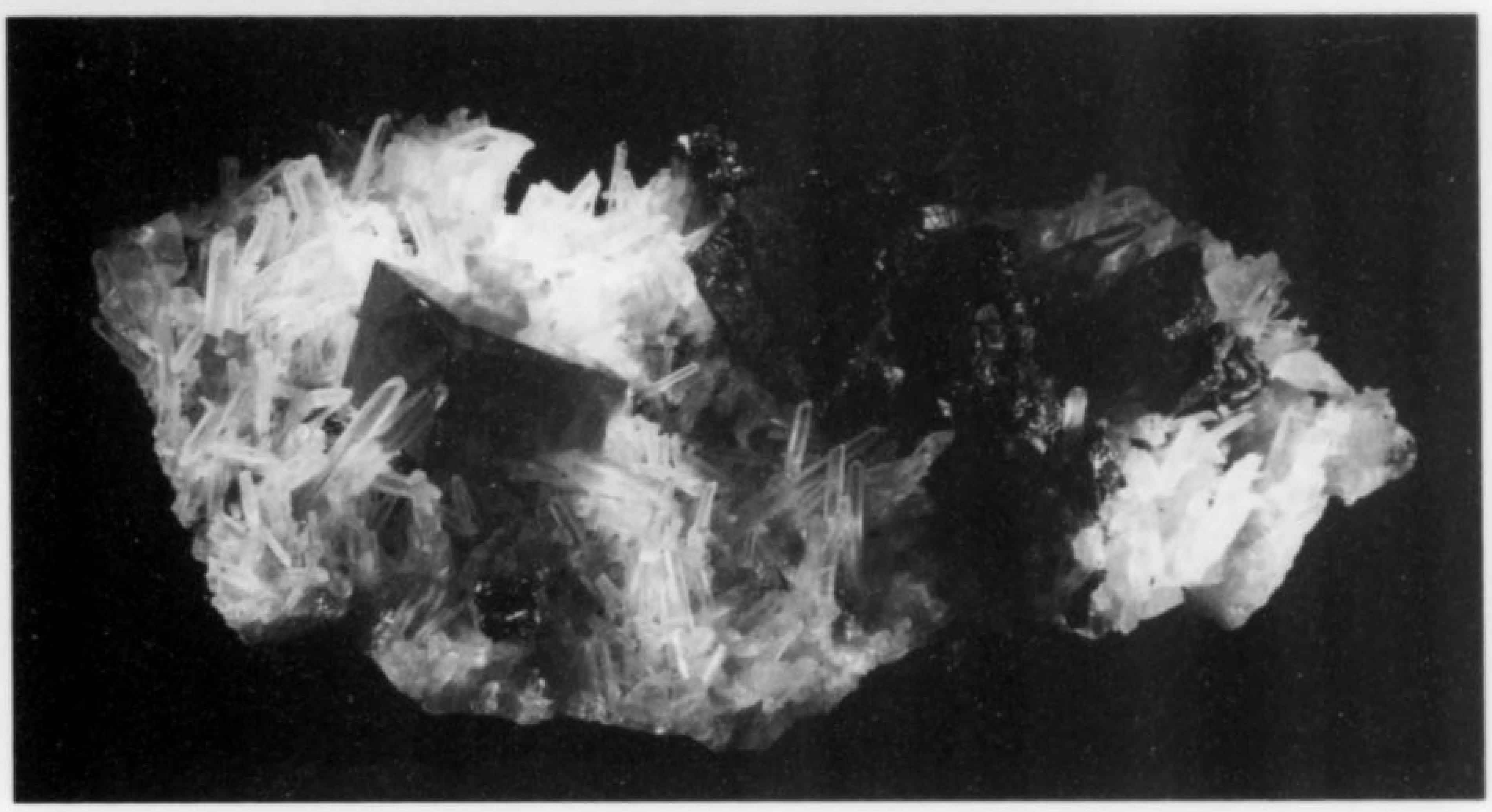


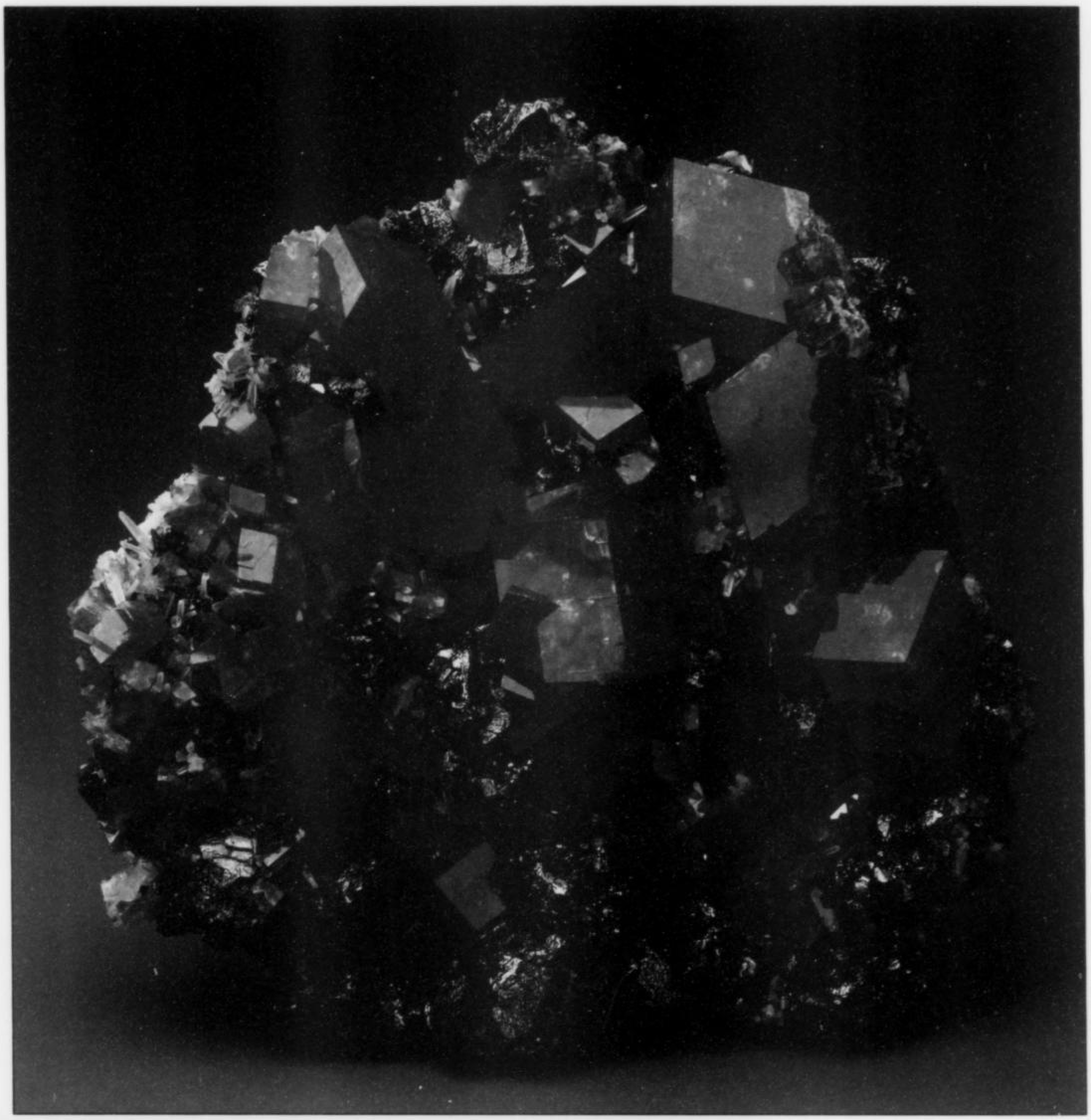
***Figure 90.* Rhodochrosite on quartz with tetrahedrite, Corner Pocket, Watercourse Raise, 10.5 cm long. Helmut Bruckner specimen; photo by Helmut Bruckner.**

and created a sort of "rhodochrosite puree." Very little material was salvaged from what would have been a killer pocket. After so much work to find them, blowing pockets up is one of the most emotionally difficult things to handle in the specimen mining process.

However, in Crosscut No. 2, there is a new pocket extension 4 feet down-drift from the original Coors Pocket opening; these two chambers eventually connect to each other above. The plates are dazzling, though they lack the white quartz casts.

October 3: In the Watercourse Raise, they drill and split into the bombed-out pocket, extracting two boxes of broken would-be killers. The hanging wall has one excellent group intact.

In Crosscut No. 2, the latest pocket (the Coors Pocket Extension) seems to be widening upward. The rhodochrosite is improving in luster, size and aesthetics.



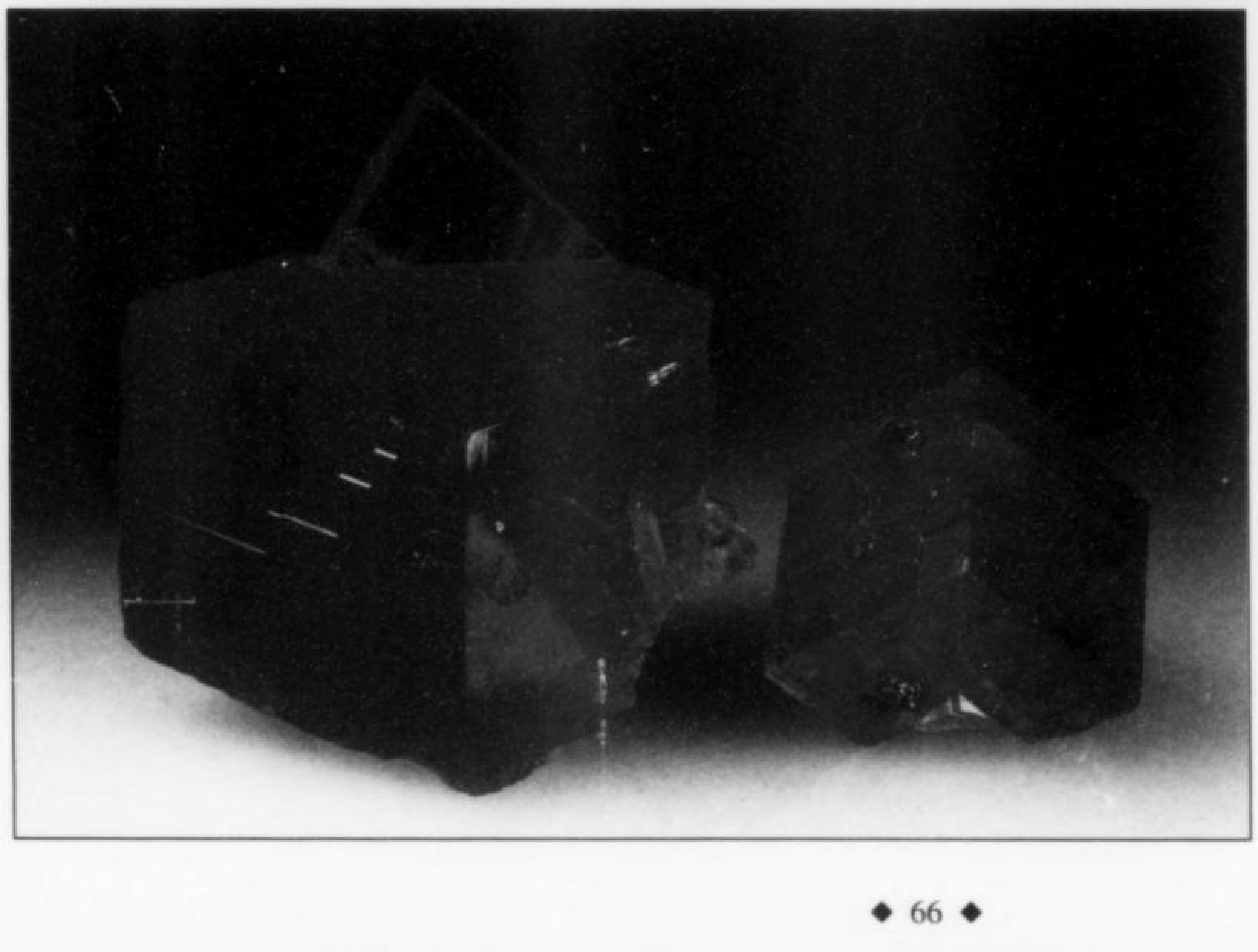


Figure 91. **Rhodochrosite with fluorite on tetrahedrite, Corner Pocket, Watercourse Raise, 13.2 cm. Note the tetrahedrite matrix. Specimens from the footwall sides of pockets commonly contain heavy sulfide mineralization. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

Figure 92. **Rhodochrosite crystals, 3.9 cm and 2.2 cm, from the Corner Pocket, Watercourse Raise. Note the sparkling sulfide inclusions in the smaller crystal. Wendell E. Wilson collection and photo.**

Figure 93. **Rhodochrosite on quartz with minor tetrahedrite and chalcopyrite, Corner Pocket, Watercourse Raise, 20.3 cm. Specimens such as this from the hanging wall sides of pockets commonly contain heavy quartz mineralization with minor amounts of sulfides. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

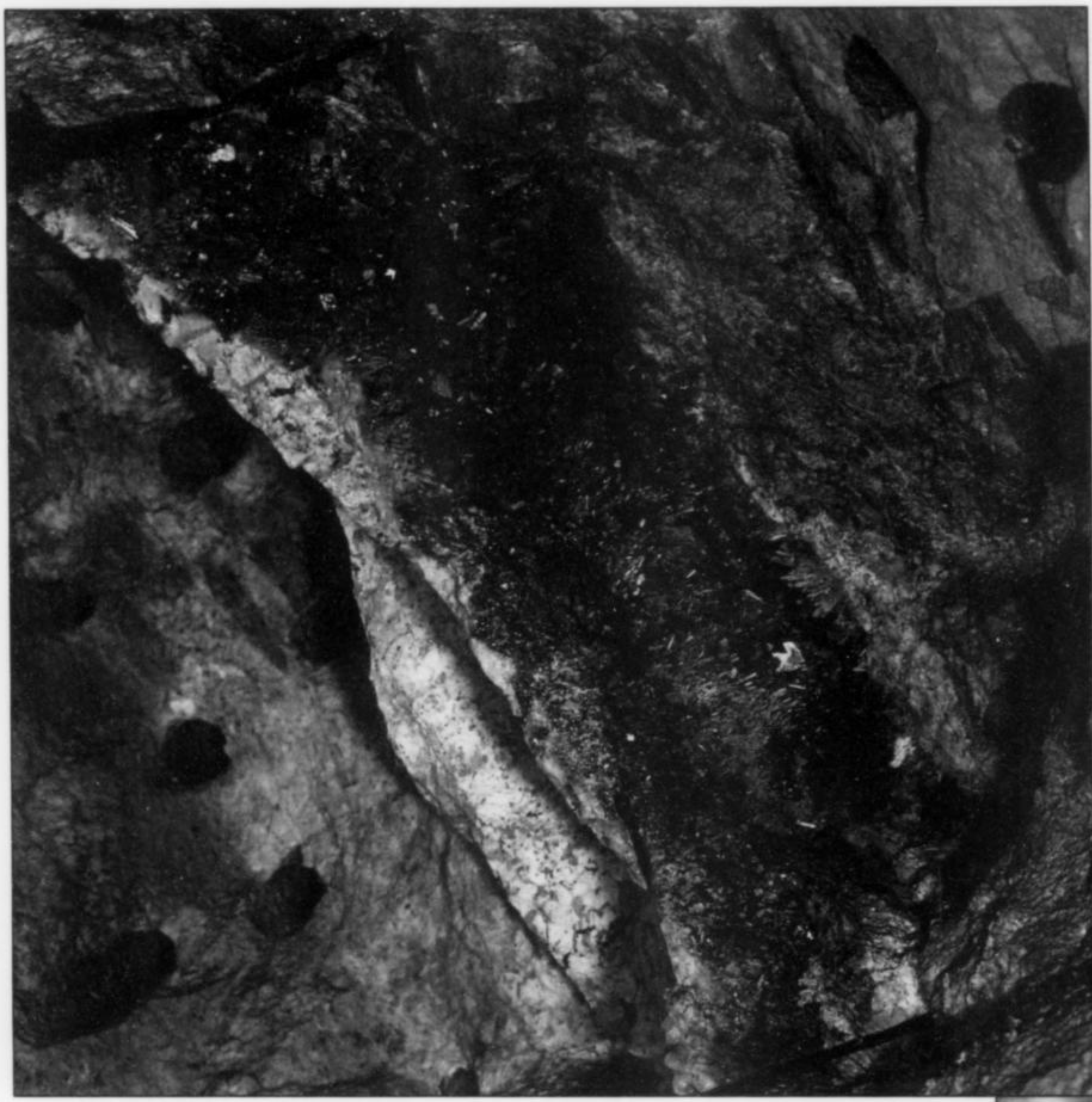
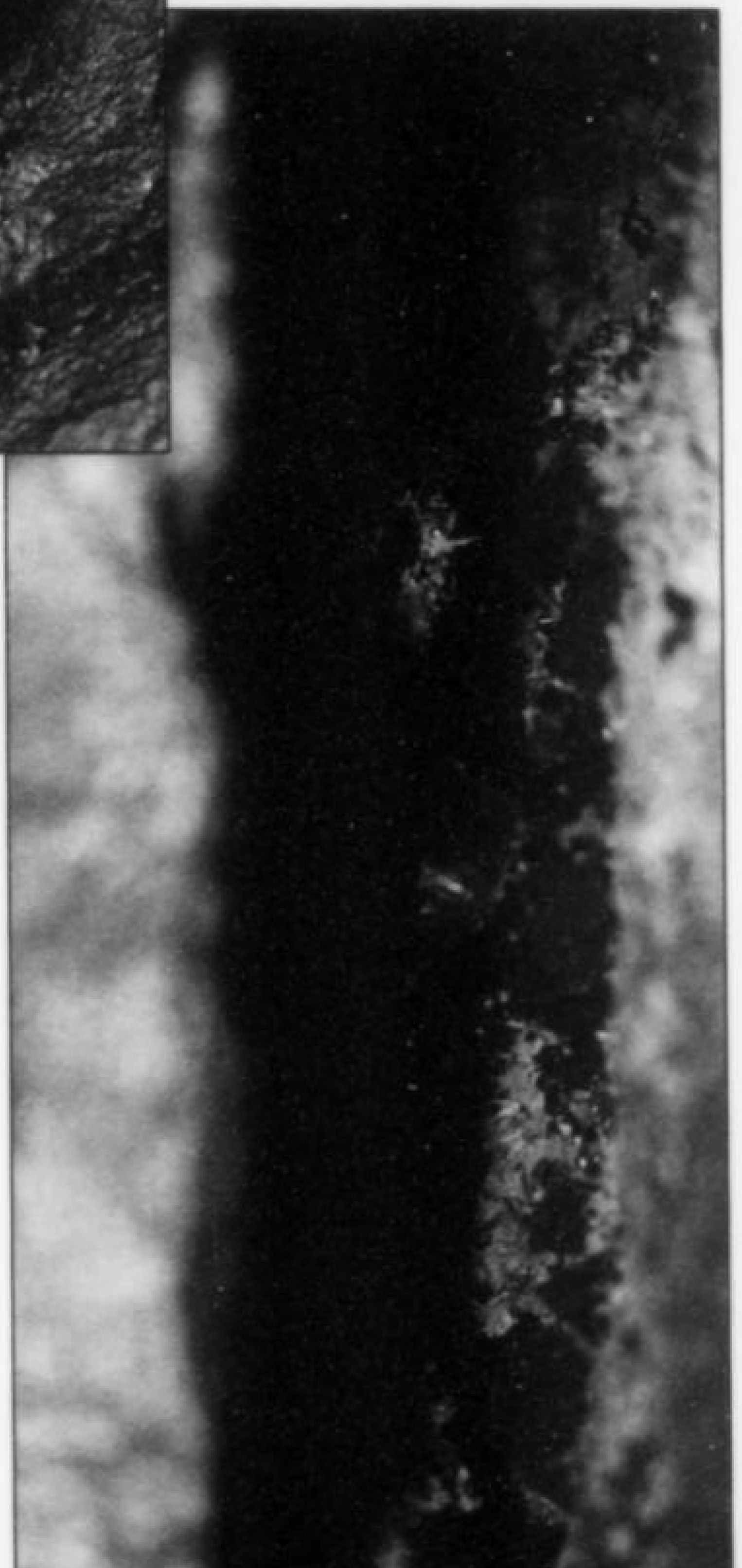


Figure 94. **Part of the Corner Pocket extending out in space. The hanging wall has been removed and the rock carved away from behind the footwall. All that remains is to remove the footwall plate from the wall. Photo by Chauncey Walden.**

Figure 95. (below) **View looking straight overhead into the Coors Pocket. The loose plates have been cleared out of the way, revealing walls studded with hundreds of crystals looming upwards into the distance. Distance between crystals growing on opposing walls is often only millimeters; this makes clean collecting very difficult. Photo by Bryan Lees.**



October 4: Three boxes of specimens come out of the Coors Pocket Extension.

October 5: Fan-drilling the back of the bombed-out Watercourse Raise pocket, they hit still another small void. The rhodochrosite here looks excellent, the color and clarity even better than in the original Corner Pocket. Rhodochrosite rhombs up to 1½ inches grow on tetrahedrite crystals. There's not much quartz.

In Crosscut No. 2, the flow of excellent pieces goes on. It looks as if the two Coors pockets are connected above.

October 6: In Crosscut No. 2, an 8-inch plate falls out from overhead and splits Bryan's nose open. They take out six more boxes of goodies from the Coors pockets.

In the Watercourse Raise, Dan and Mike drill and split into what's now called the Corner Pocket Extension.

October 10: In the Watercourse Raise, they hit a new, small pocket on the left rib of the raise opposite the Corner Pocket side.

October 11: In Crosscut No. 2, the Coors Pocket complex is tightening up and becoming more difficult and dangerous.

In the Watercourse Raise, the Corner Pocket Extension opens up. Though small, it gives up three highly lustrous, first-rate miniatures. Meanwhile, the new left-rib pocket is opened a bit. Nothing is collectible from here yet.

October 12: As collecting continues in the Coors Pocket complex in Crosscut No. 2, the new left rib pocket in the Watercourse Raise starts yielding brilliantly lustrous rhodochrosite rhombs sprinkled with lustrous purple fluorites. The pocket measures about 14 x 8 inches by only 1 inch wide.

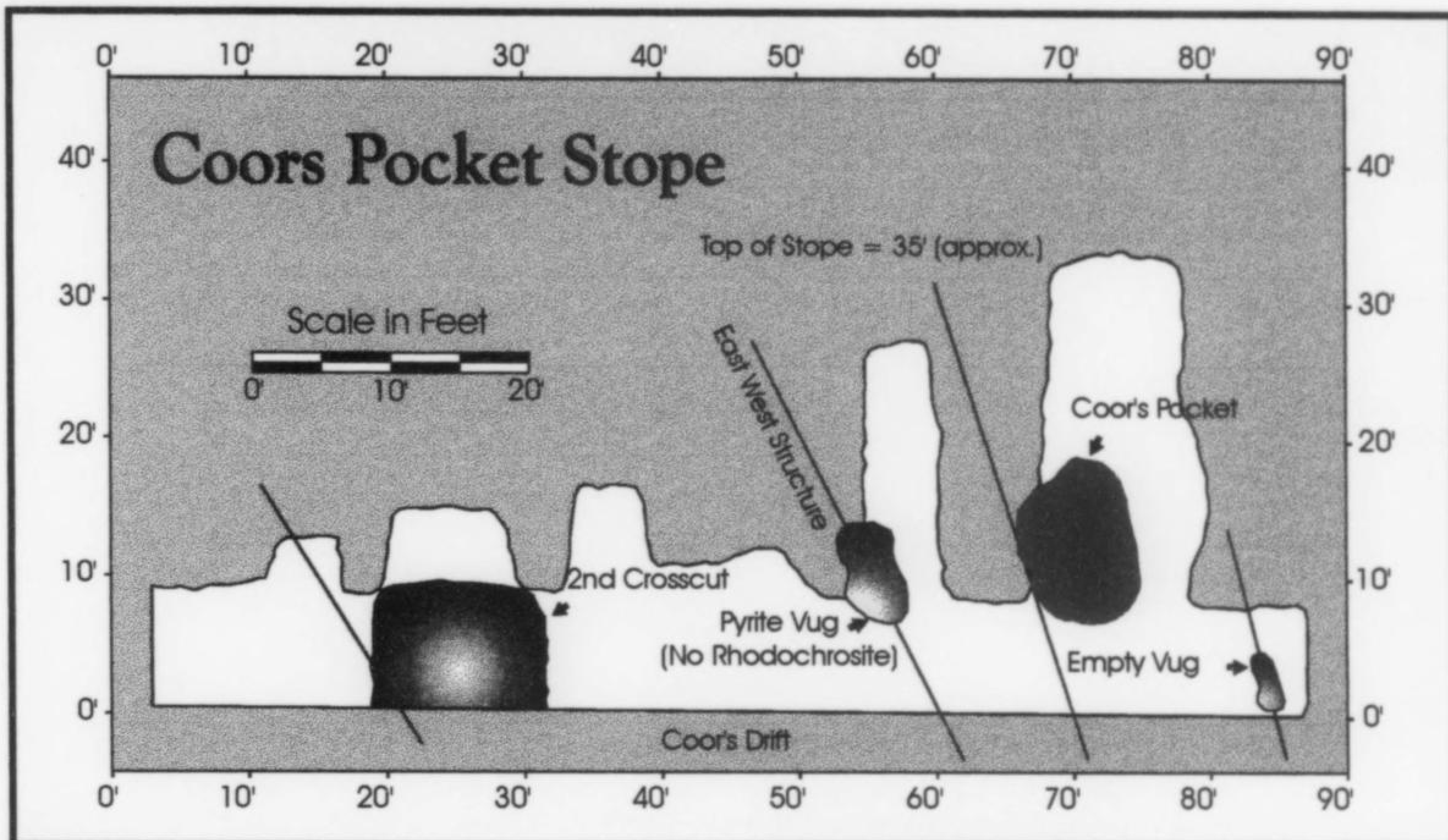


Figure 96. **Section of the Coors Pocket Stope, looking east. Graphics by Bill Tanaka and Bryan Lees.**

SWEET HOME MINE
ALMA
COLORADO

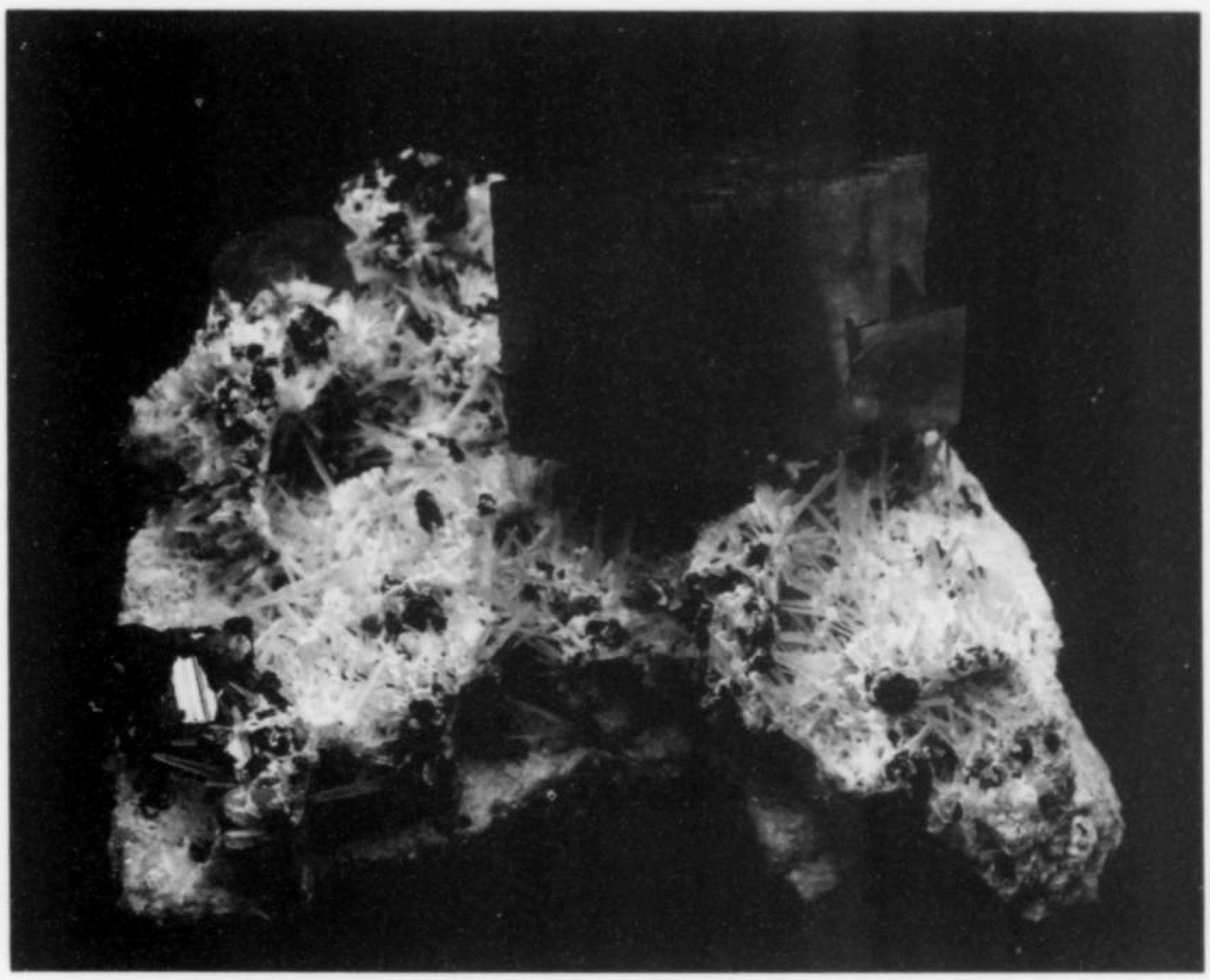


Figure 97. **The "Tower of Terror" rhodochrosite, Coors Pocket, second crosscut, 11 cm wide. Denver Museum of Natural History collection; photo by Jeff Scovil.**

***Figure 98*. Scott Betz's hand demonstrates the crystal size on the best, large matrix plate collected from the Coors Pocket. Photo by Bryan Lees.**

October 13: Small pockets continue to open up on the left rib of the Watercourse Raise. Dozens of thumbnails and miniatures come out—vivid rhodochrosite rhombs, ¼-inch blue fluorites and water-clear quartz needles. This is the best group of thumbnails in four years.

Production slows in Crosscut No. 2 as the Coors Pocket complex tightens up again, though there are still many beautiful large rhombs stuck to the walls up high. David Basinger and the Denver Museum of Natural History video crew come up and videotape the work.

October 17: In the Corner Pocket Extension in the Watercourse Raise, another small vug appears. The rhodochrosite rhombs are up to 1¼ inches, with quartz and nice tetrahedrite crystals.

In Crosscut No. 2, Bryan brings up some new 18-inch chisels to get further up inside the Coors Pocket complex. The results are excellent. Tomorrow they will try to diamond-saw a great hanging-wall piece.

October 18: In Crosscut No. 2, the hanging wall plate is brought down and out (Fig. 98). It is 14 inches across with six sharp rhodochrosite rhombs to 1¾ inches—no damage, and extremely aesthetic. The vug is inexorably tightening up, however.

October 19–30: Collection of the Coors Pocket complex is completed during this time. At the shop, the piece count exceeds 3000. More than 1000 of them are top quality specimens. The whole pocket complex seems to be 8 feet in diameter.

In the Watercourse Raise, collecting continues through the end of the month. This Corner Pocket Extension region (with too many small vugs to name individually) produces exquisite small specimens—dozens of "competition" thumbnails and miniatures whereon the very sharp, highly lustrous and gemmy medium-pink rhodochrosite rhombs seem to float a bit above the needle quartz beds. Bryan names these ethereal things "pink clouds."

November 1–December 8: In Crosscut No. 2, Scott punches a raise 30 feet above the big, initial Coors Pocket and finds nothing. He moves back toward the Crosscut and puts in four more small raises. Only one of these, 10 feet from the Coors Pocket, produces more material—though only three really good specimens—with rhodochrosites exhibiting a curved habit, rather like the ones from the Sunnyside mine, Silverton, Colorado. This last strike is called the After Coors Pocket.

Meanwhile, back in the Watercourse Raise, Mike and Dan go another 35 feet up from the original Corner Pocket, following good-looking structure but finding nothing. On December 1, they decide to abandon this raise and start a parallel one 20 feet away on the other side of the raise. A new, small, nice pocket (unnamed) is hit at once and produces the last killer of the 1994 season.

December 18: Final pull-out and end of season.

THE 1995 SEASON

Events at the Mine

1995 resembled 1993 in many ways. A few small pockets were hit early on, but August and September passed without major strikes and the season ended without the mine having done much more than tease the crew.

The primary 1995 target was the Main Stope, where the 1966 strikes and the Good Luck Pocket of 1992 had occurred. The strategy was to raise the stope upward to the 200-foot level to see if there were any more pockets left along the favorable structure. The highest raise they had made earlier reached only 100 feet. To get higher, they had to hire additional crew: Mike Savage, Jim Smith and Rodney Orton, all experienced raise miners. The stope itself, as it developed, measured only about 60 feet wide, with pillars left behind for support and muck storage.

Part of the general 1995 bad luck was that they accidentally blew up most of the season's best pocket, dubbed "Murphy's Pocket." It lay just beyond the end of a series of drill holes and the blast shook it so violently that what would have been, Bryan estimates, about $200,000 worth of crystals were turned into cutting rough. Ironically, the calamity happened on August 21, three years to the day after the Rainbow Pocket was breached in 1992. It was a memento

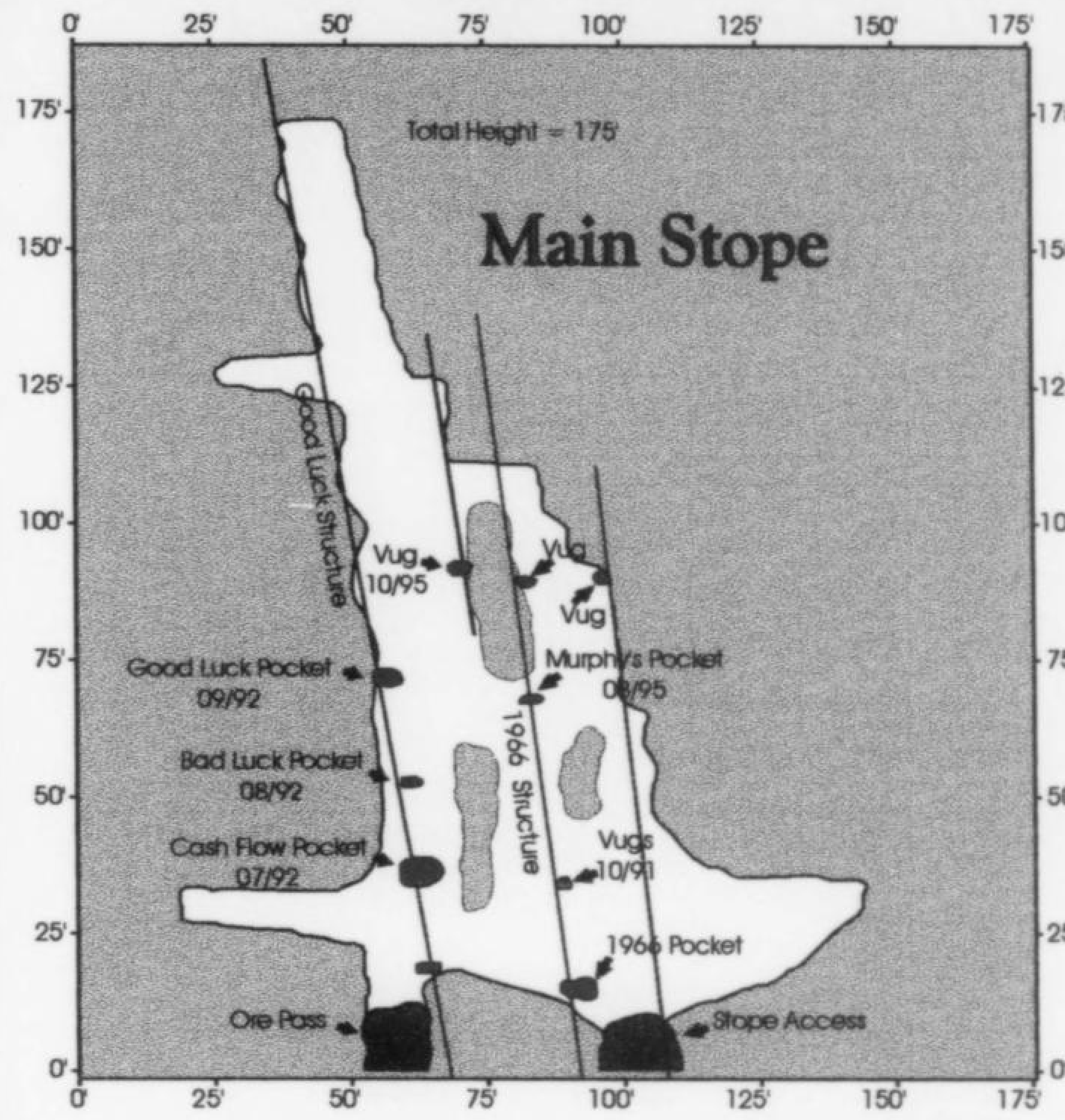
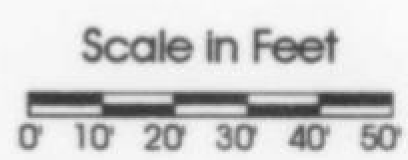


Figure 99. **Section of the Main Stope, looking east, in 1995. Graphics by Bryan Lees and Bill Tanaka.**



mori: that earlier blast had stopped only about 12 inches short of similarly blowing up the Alma King.

Throughout the 1995 season, rock was moved at a good pace and much new data were gathered, but nerves wore thin and no big payoff came before the mine was shut down on December 13.

Events Behind the Scenes

August of 1995 saw the second of my trips to check out the operations of Sweet Home Rhodo, Inc. On this occasion, I put in the bulk of my time—several days—in the two-story warren of offices, labs, storage space, showroom and general busy percolation that is The Shop. Not only is the Collector's Edge Minerals, Inc. mineral company headquartered here, but also, these days, the extensive support system for the Sweet Home mine. The intensity of activity seemed even higher in 1995 than it had a year before. Historical photos, show posters and antique maps hang on the walls, the odd Sweet Home Lager bottle looks down from shelving, and everywhere, of course, there are specimens.

In the downstairs office, there is a filing cabinet full of Sweet Home-related documents. Anyone who thinks it's administratively easy to run even a small modern U.S. mine operation might check out these drawers tightly packed with folders full of papers pertaining to, among other things, insurance and legal affairs, permitting procedures, minutes of Board meetings, MSHA training guides, safety rules and scientific studies. These latter include an age-dating project, two petrological studies, a rose-diagram study of fracture systems, ground-penetrating radar returns, X-ray work, surface surveys, a manganese oxide study, much more geochemical work . . . and so on.

Of all the studies to which the Sweet Home project has given rise, Bryan is most pleased with the research on crystal chemistry and fluid inclusions (see articles by Karen Wenrich and Jim Reynolds, this issue). Obviously a close understanding of the relations between crystal quality and chemistry and pocket distribution within the mine would help the company know where to look for the most beautiful specimens. To refine the work on this problem and others, the company uses AutoCad (Automatic Computer-Aided Design). This program maps the mine, drawing pictures of structures and manipulating elements of them in either two or three dimensions and to any scale. It stores relevant data in "layers" so that any combination of data can be called up and

Figure 100. **Rodney Orten uses the hydraulic splitter to open a pocket in the Watercourse Raise in 1995. This pocket proved to be empty, as most pockets at the Sweet Home mine tend to be. Photo by Bryan Lees.**

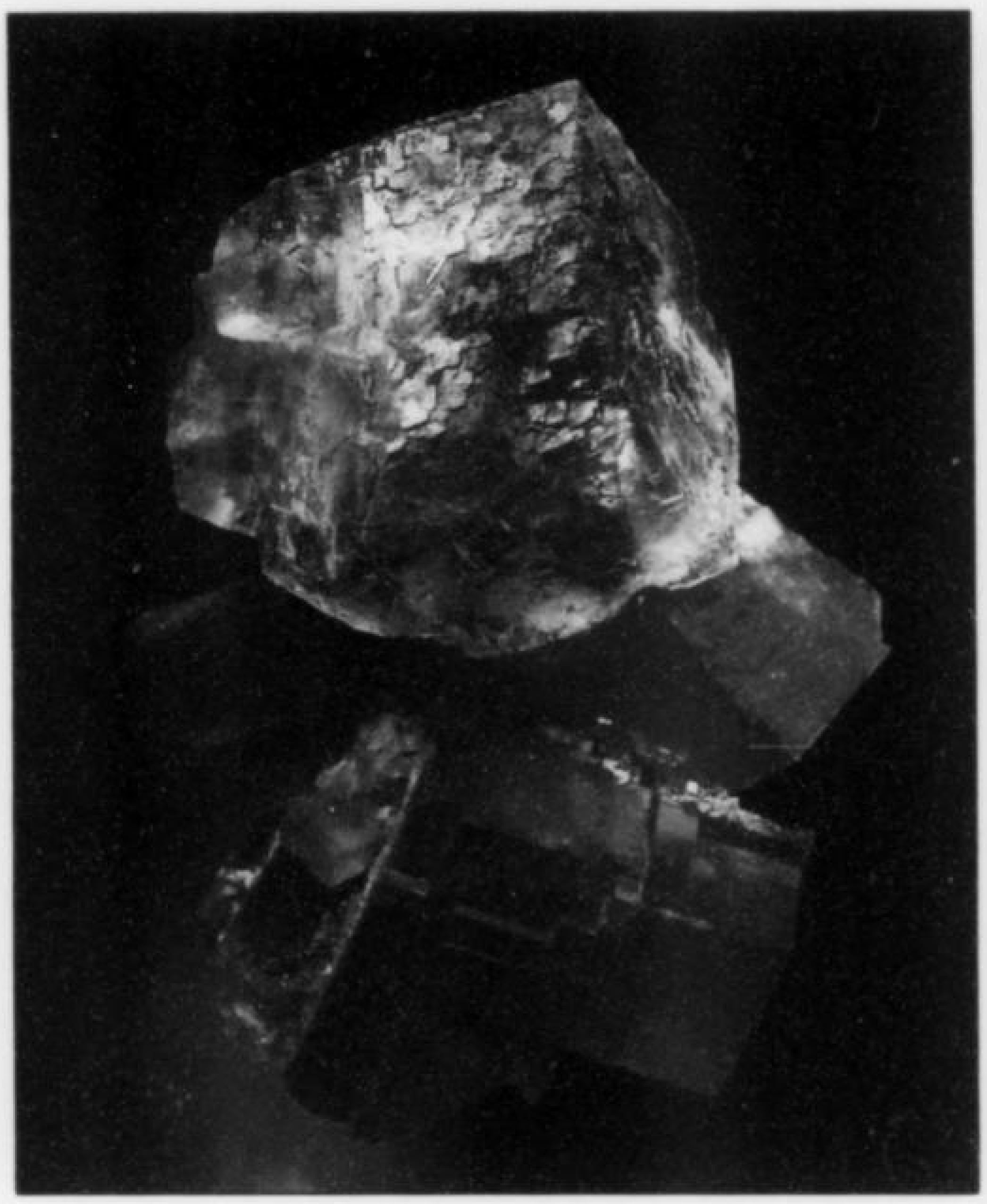


Figure 101. Fluorite on rhodochrosite, Murphy's Pocket, Main Stope, 4.1 cm high. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil. This was the only good rhodochrosite specimen saved from a blast that ripped through this beautiful pocket.

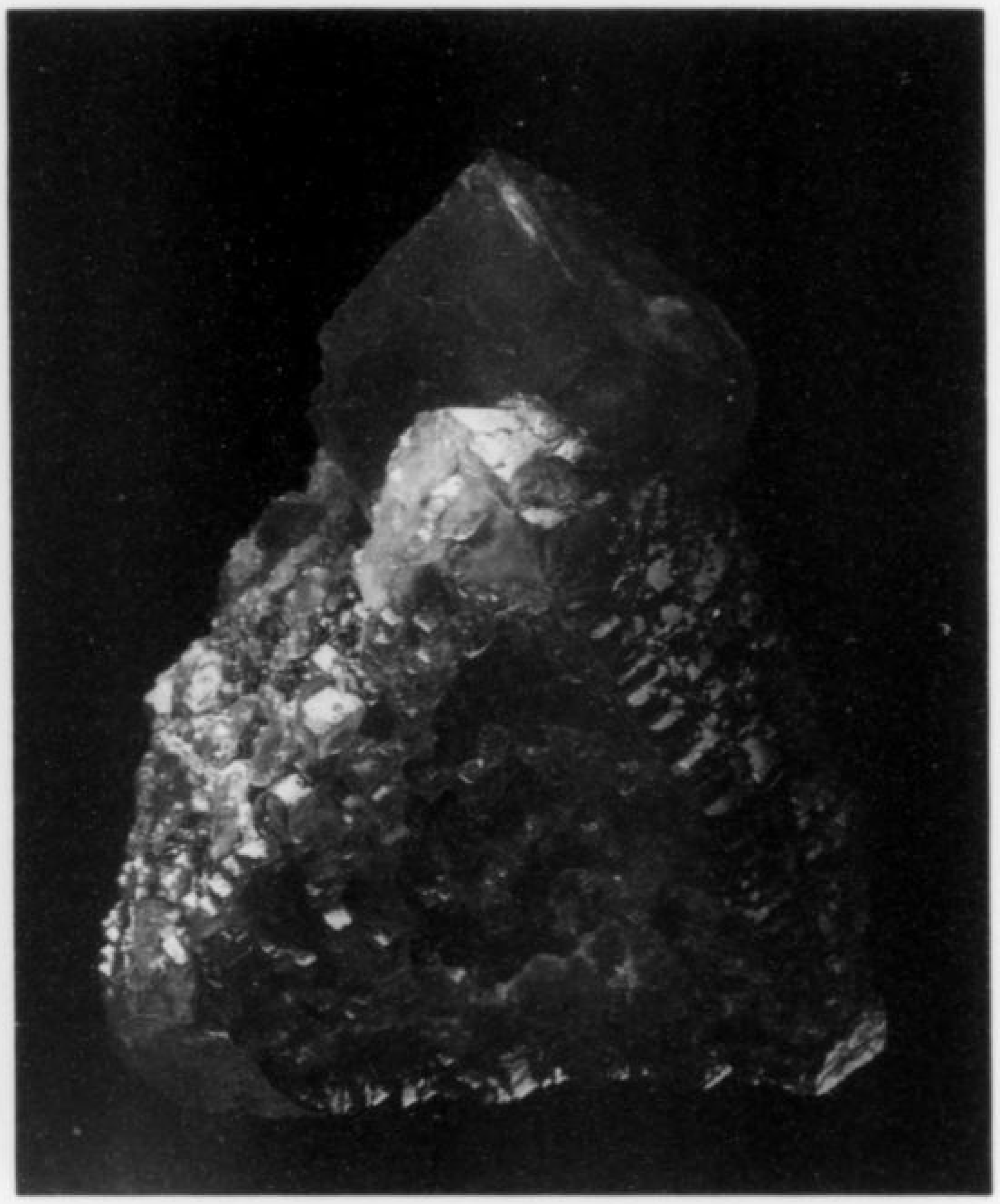


Figure 102. Fluorite with rhodochrosite, Horseshoe Pocket, New Tetrahedrite Drift, 4.4 cm high. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.

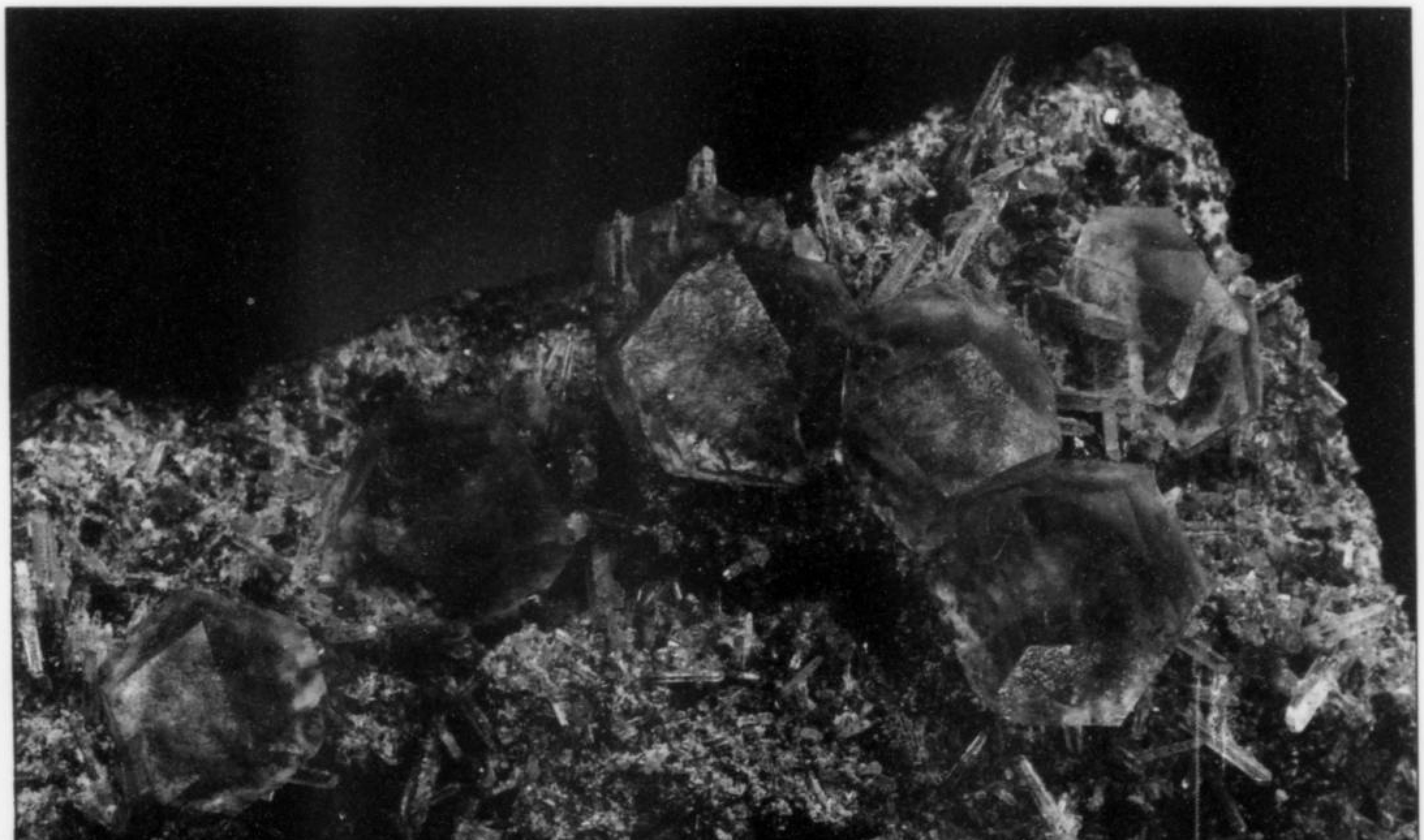


Figure 103. Fluorite, Murphy's Pocket, Main Stope; the crystals are 1.1 cm in diameter. Note the dodecahedral crystal habit. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.

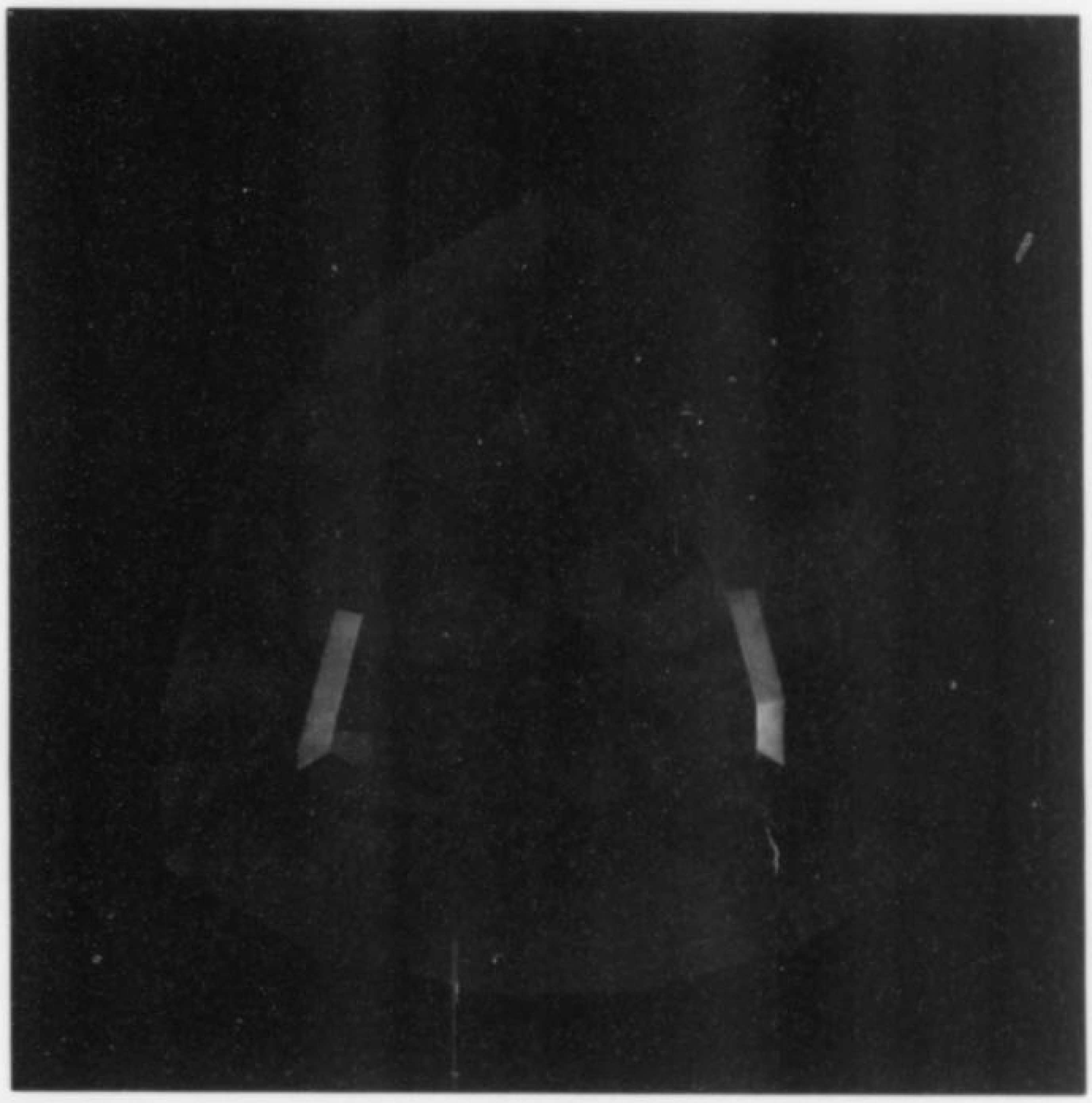


Figure 104. **Rhodochrosite, Main Stope, 50.28 carats. Anonymous collection; photo by Jeff Scovil. When pocket contents are damaged, the crystals may still have some clean interior areas. If so, they are usually faceted into gems such as this one.**

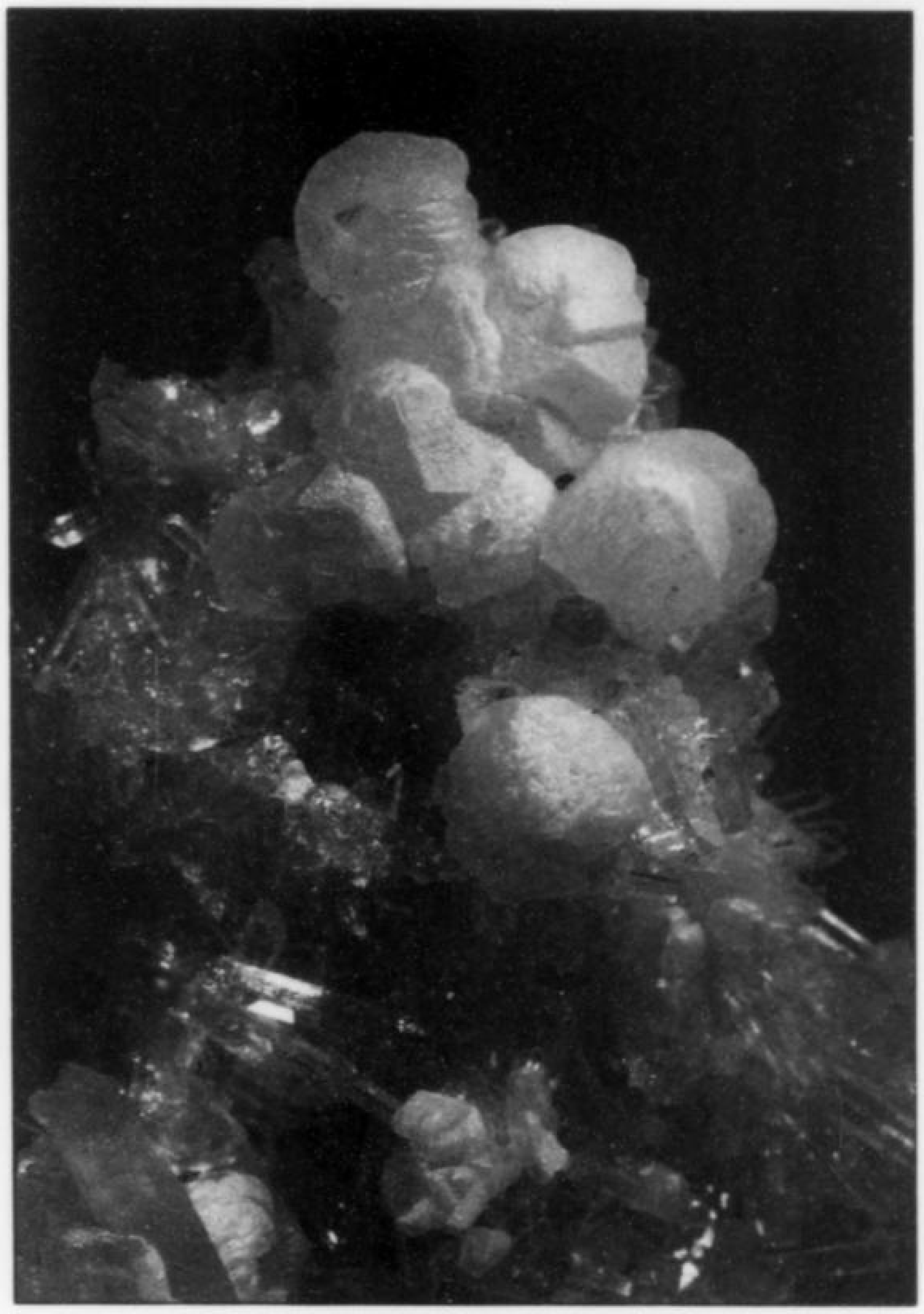


Figure 105. **Calcite on quartz, third crosscut, 6.2 cm high. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil. Such late-stage calcite is occasionally found on pocket walls.**

superimposed on the map. Among the most important of these data layers are faults and fault systems, mineralized veins, pocket locations, ground-penetrating radar (GPR) targets, and all observations made in the field by Dean Misantoni and others. Gene Kooper, a geological engineer from Denver, Colorado, devoted hundreds of hours to converting field maps into AutoCad files.

During the off-season, the company uses AutoCad to look at different parts of the mine with different superimposed combinations of data (including those from the crystal-chemical studies) in order to plan mining strategies for the next season. Zooming in on an area of the mine, noting trends and extrapolating them, Bryan can decide, at least tentatively, in which direction to drive new drifts and raises, and how much rock will have to be moved. Typically, a target is picked, a map is printed showing all pertinent data, and it is reviewed by Dean and the Sweet Home management team for practical study and feedback.

Early in the Sweet Home operation, rumors developed that ground-probing radar would make optimal mining strategies practically self-evident. The sober fact is that GPR, so far, has enjoyed only partial, rather ambiguous success in the mine (see article by Bryan Lees, this issue). Some of the early GPR targets turned into real pockets, some did not, and not all of those which did were worth the work of getting to them. Dean Misantoni:

> The GPR is all right, it's had some success here, but it wasn't really made for underground mine work. It was made for things like finding weak spots in landfills in Florida. You have to know the structures to know where the GPR anomalies really might be crystal pockets. It's only if you know where the strings are that GPR can show you the pearls.

Thus, if more bonanza pockets are found, the success will be credited more to geological legwork, sharp observation, common sense, uncommon instinct and good science, with AutoCad providing the high-tech synthesis of all these, than to any magic in GPR alone.

The specimen-preparation activities of the Collector's Edge, with special emphasis on Sweet Home mine products, are a major

Figure 106. **Rodney Orten uses an LHD (Load Haul Dump) to remove blast rock from the bottom of the Main Stope in 1995. Photo by Bob Jones.**

Figure 107. (below) **All muck (blast rock) must be removed from the mine site. First, the rock is placed outside. Then, an excavator loads it into a truck for transport to a dump site several miles from the mine. This is very expensive, but allows the mine to stay in operation. The muck was formerly backfilled into old tunnels underground, but unfortunately the miners ran out of backfill space in 1994. Photo by Bryan Lees.**

component of daily work in the shop. The main men to see here are the Collector's Edge "rock doctors" Robert Lorda, a geology student at the Colorado School of Mines, and Bill Hawes, an experienced fossil and mineral collector. The Collector's Edge is widely regarded as having one of the world's finest mineral specimen cleaning and preparation facilities, but many of its procedures still are improvised. There is almost no published literature on this arcane activity and not more than 20 people on earth who engage in it full-time. The Collector's Edge has learned much, Robert says, from fossil preparers, who are more numerous than rock doctors. And yes, there are trade secrets. Much that the mineral company has learned from experimenting on and even ruining specimens (sometimes deliberately) represents a very hard-won knowledge, so the alchemist might understandably feel a proprietary claim.

Nowadays most of the daily lab work consists of preparing specimens from recently mined Sweet Home pockets. Information regarding specific techniques is "sensitive," and, in any case, no quick summary of them could convey the delicacy, creativity, agony and ecstasy of the more than 500 hours of work, experimentation and sloshing around in dangerous chemicals done by Bill Hawes to ready the Alma King and Rose for their coming-out in Tucson in 1993.

It's a good thing that the Collector's Edge alchemists had taught themselves so much rock-doctoring and had gained some real confidence in their skills by the time the Coors Pocket was hit late in the 1994 season. A major educational project was in the offing.

Bryan Lees:

> Just after the final material was taken from the Coors Pocket, we had an opportunity to present a concept to Bill Coors [current head of the Coors Foundation]. The concept was to rebuild the Coors Pocket and install it in the Denver Museum of Natural History. Mr. Coors liked the idea and work began

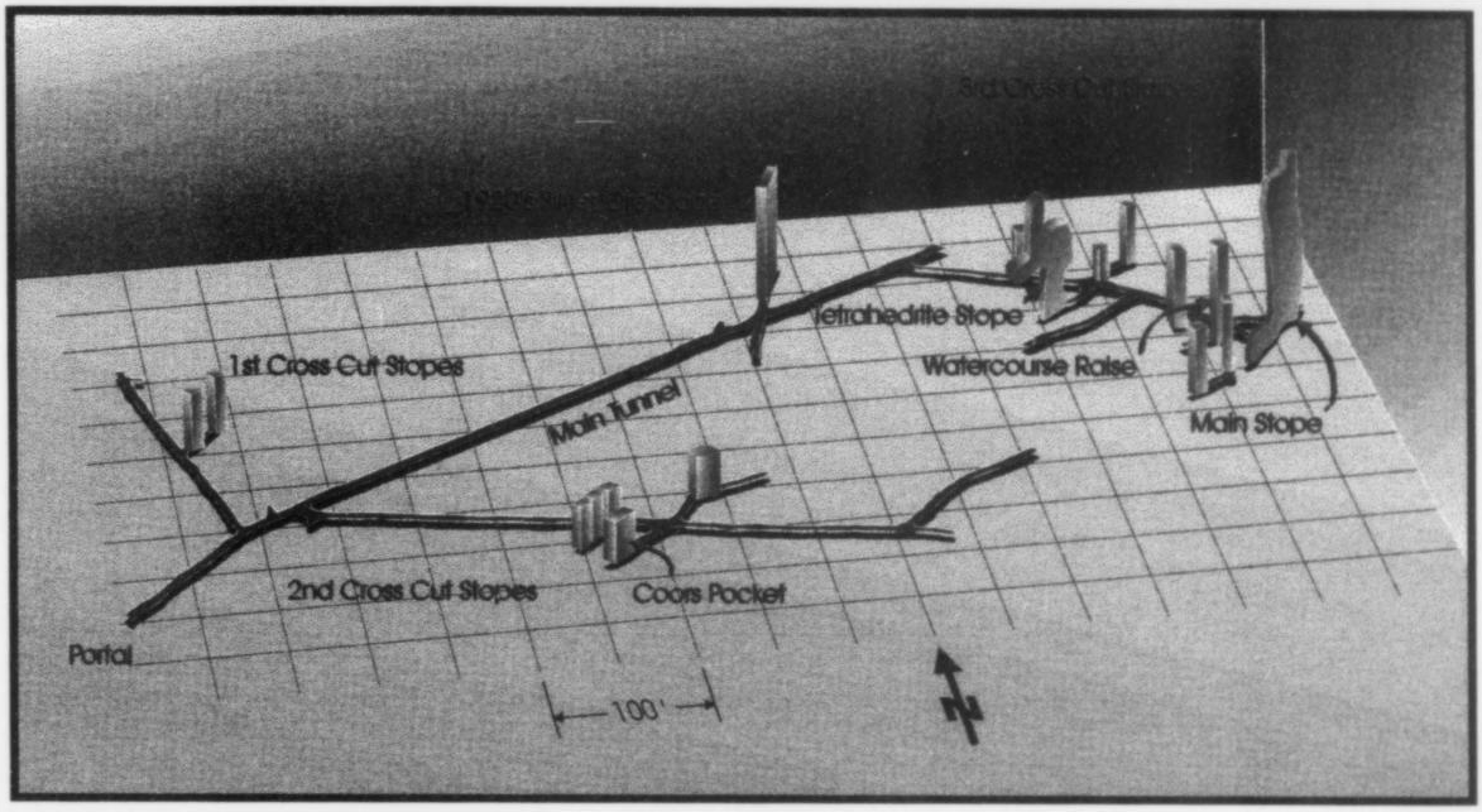


Figure 108. **Schematic 3-D cutaway diagram showing the locations of productive stopes found during 1991 through 1997. Graphics by Bill Tanaka.**

SWEET HOME MINE
ALMA
COLORADO

on designs. In the spring of 1995, both the Museum and the Coors Foundation endorsed the project and work began. The finished pocket would be about 8 feet in diameter and would include 3000 individual specimens. Months of design work, engineering, specimen cleaning and meetings between the company and the museum resulted in a comprehensive plan, outlining every facet of the exhibit—its location, pocket design, maintenance, lighting, interpretation and mount design.

The 3000 individual pocket pieces would first be combined into about 15 subplates, each subplate containing about 200 pieces. The subplates would then be attached to a large steel frame. All seams and contacts would be carefully camouflaged. This work would be done at the Collector's Edge facility in Golden. The tunnel recreation, exhibit room, interpretive exhibits, plate interfaces and lighting would be produced by museum staff. Time allocated for production was about two years.

A visitor to the back room of the shop in the summer of 1995 encountered a huge "sandbox" covering part of the floor. About 100 magnificent matrix rhodochrosite specimens were scattered about on a bed of pea gravel in the sandbox. The rest of the 3,000 pieces in question filled metal shelving on the back wall. Hundreds of the specimens are top collector pieces—matrix specimens with rhodochrosite rhombs up to 3 inches on edge, deep red, translucent

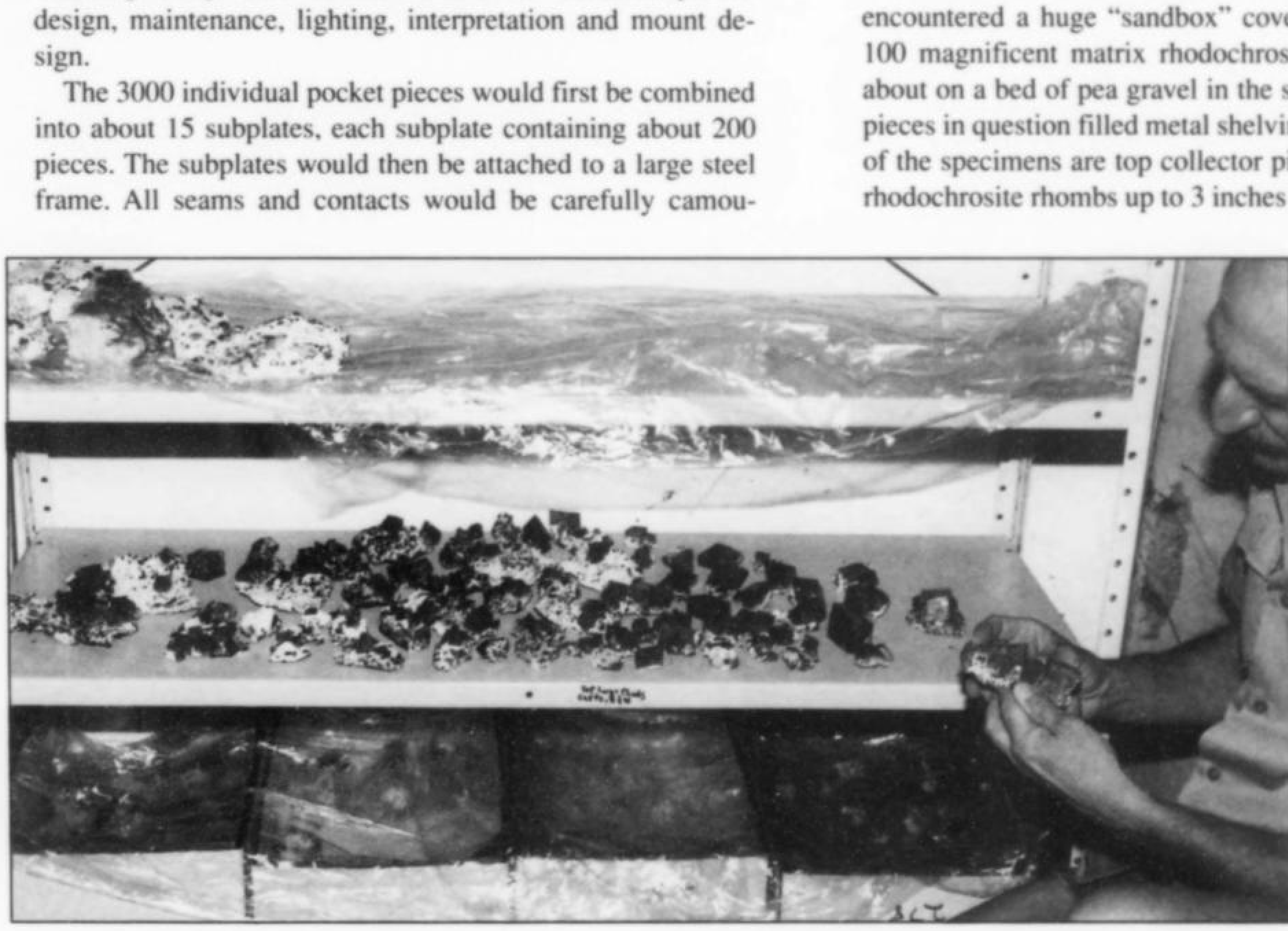
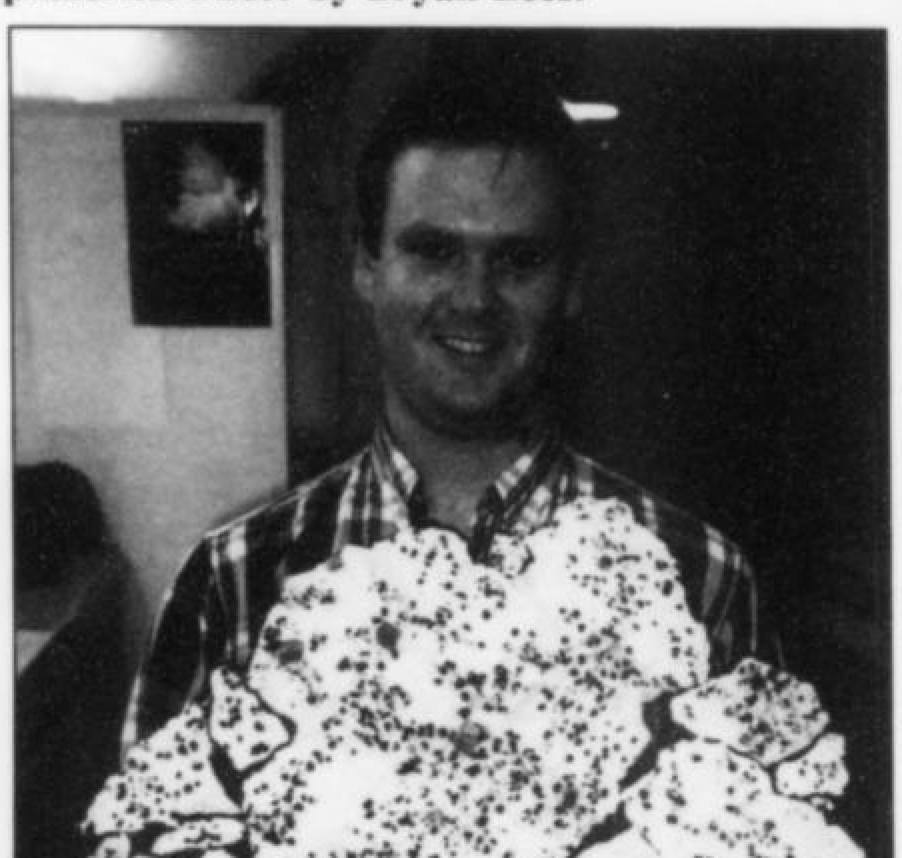


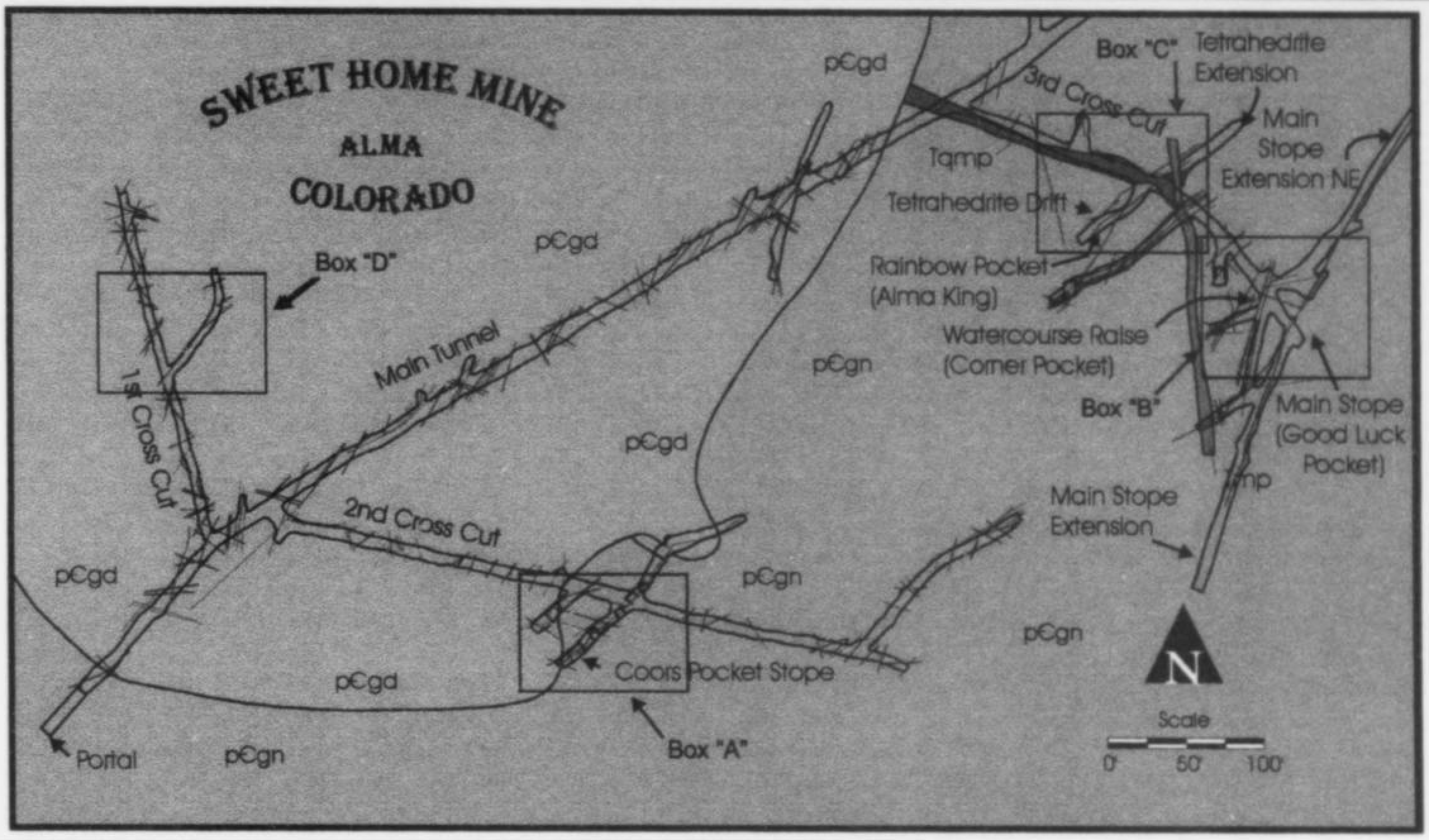
Figure 109. **Bill Hawes inspects the cleaning job on the Coors Pocket rhodochrosite specimens. The pieces were so dirty that they each had to be cleaned 3 or 4 times in order to remove the heavy iron staining which permeated the entire pocket contents. Photo by Bryan Lees.**

Figure 110. **Three of the Coors Pocket "subplates" are fitted to the steel frame. Faux rockwork (green, and not yet painted) will be added to the frame to copy the look of the original pocket. All of the plate margins must fit exactly and the faux rock must blend in perfectly. Photo by Bryan Lees.**

Figure 111. **Bill Hawes (right) shows Kirby Siber the first stages of pocket reconstruction; the "mockup." First, an 8 by 8-foot sandbox is constructed. Then the pieces are arranged according to their position in the original pocket. Photo by Byran Lees.**

Figure 112. **Robert Lorda displays a section of a "subplate." A finished "subplate" will consist of about 200 individual pieces. The dark mineral is sphalerite. Photo by Bryan Lees.**





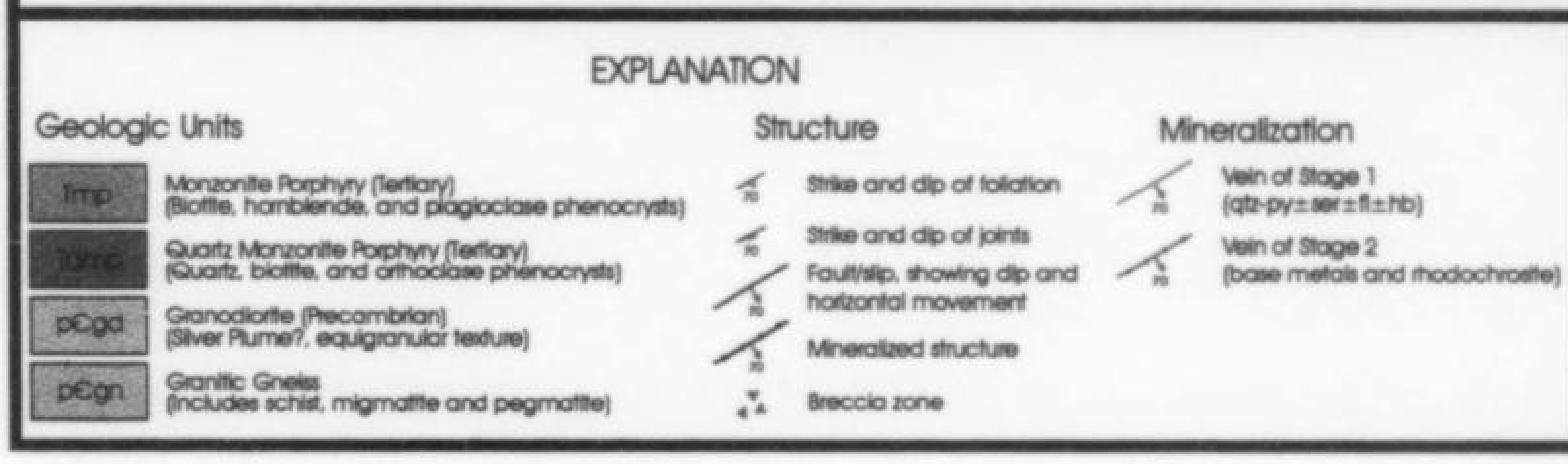


Figure 113. **Simplified geologic map of the Sweet Home mine, showing lithology, structure and mineralization. Graphics by Bill Tanaka and Gene Kooper.**

and sharp, though not of the highest luster. The work clearly would be enormous—an estimated 12,000 hours of design, engineering and reconstruction work, both at the shop and at the Denver Museum.

Bryan explained to me that to fit the edges of the individual specimens together they would be filed and shaped, and the gaps filled in with bits of wall rock or thumbnail rhodochrosite specimens creating large aggregates called "subplates." Each subplate would be epoxied together underneath and a supportive layer of epoxy-infused fiberglass added to strengthen seams while keeping the overall weight down. The fifteen large subplates would be attached to a frame with specially designed connecting bolts. The whole thing would be partially taken apart again just to get it out of the shop, then reassembled at the museum. Finally, the museum would add ambiance. When reassembled, full illumination will reveal the pocket receding up and away on a 15-degree slope. Distantly, from behind the walls, sounds of drilling, miners' voices and dripping water will be audible. This experience, together with the display of the Alma King, will symbolize Colorado's mineral wealth and mining heritage in a most appropriate and publicly accessible place.

To help handle this task, two new preparators were added to the Collector's Edge team. Denise Patton and Mark Akerley teamed up with the rest of the crew for the push to complete the project. The exhibit's opening at the Denver Museum of Natural History took place in May of 1997.

The last stop on the shop tour is upstairs, where Kathryn Lees, among other duties, handles the inventorying and archiving of all that has ever been dug at the Sweet Home mine. Until 1993, every specimen got an "SH" number. Now, only those which exceed a certain value do. Keyed to these numbers is information on specimen provenances by pocket, stope and raise, and sale records. Best of all, these data finally will be stored at the Denver Museum of Natural History. Collectors who come to own pieces from the Sweet Home mine should, of course, save the Collector's Edge labels that come with the specimens, but they might also enjoy knowing that all information of interest about their specimens will be preserved forever in the museum archives.

THE 1996 SEASON

Going into the 1996 season, the Sweet Home crew were hoping they were past the "odd year curse." By now it was obvious that the odd years were not producing any significant crystal pockets. Some people joked about simply closing the mine during these years. The "curse" was creating havoc with the company's cash flow and making it very difficult to stay in business. This being an even year, therefore, created much optimism among the crew. It would not be long before that optimism paid off: 1996 turned out to be one of the operation's best years.

There were no crew replacements; indeed there was one addition. Tony Sherrill joined the Sweet Home crew, which included Bill Kazel, Bryan Lees, Scott Betz, Dean Misantoni, Roy Rizzardi, Mike Warren and Rodney Orton.

During the winter months, Bryan Lees and Bill Kazel planned to sink a winze underneath the Main Stope area to look downwards for pockets. All other areas around the Main Stope were suppos-

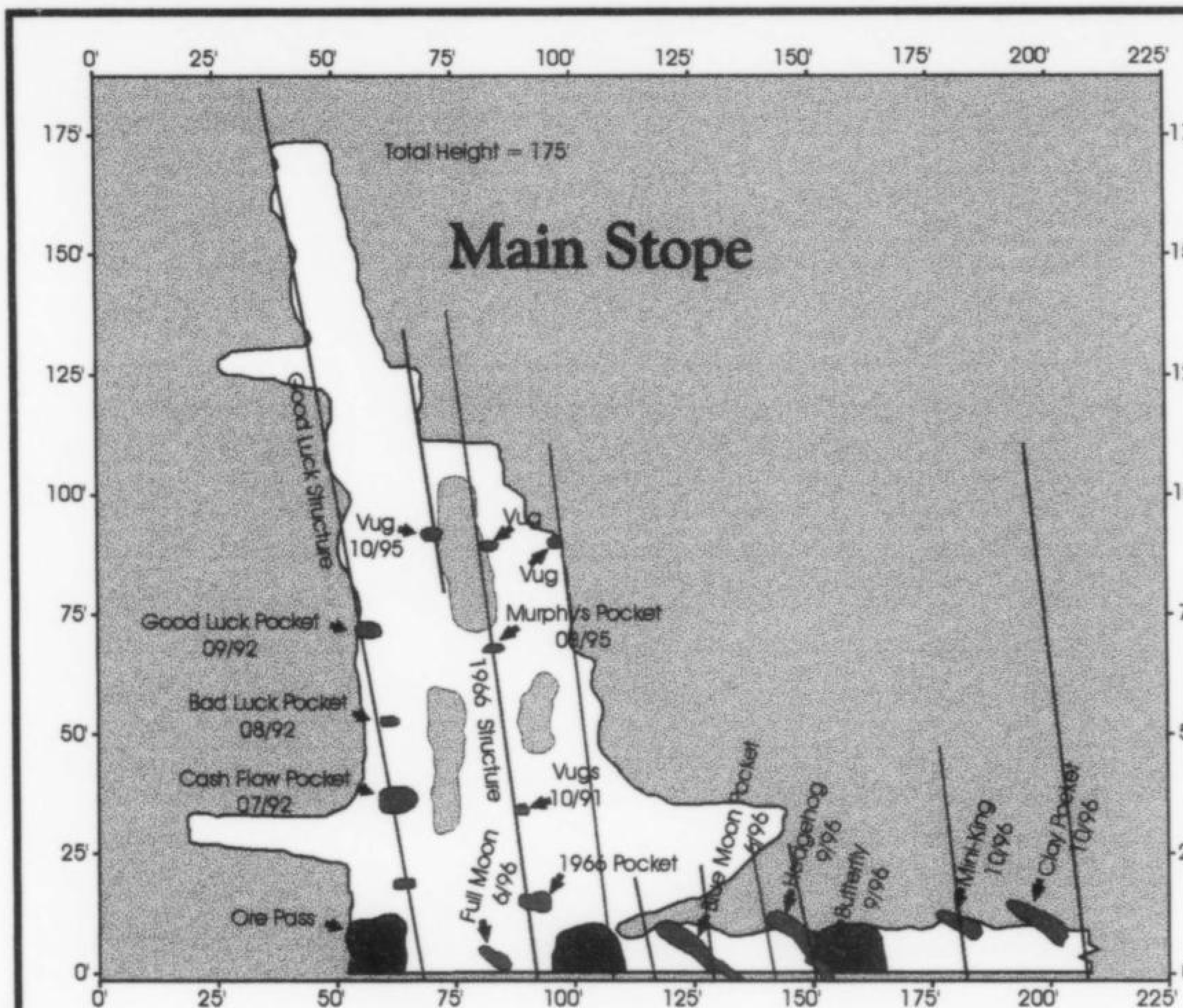
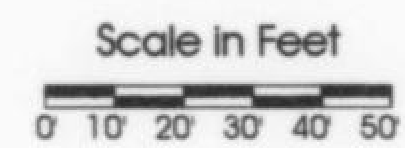


Figure 114. **Section of the Main Stope, looking east, in 1996. Graphics by Bill Tanaka and Bryan Lees.**



edly worked out. This would not turn out to be the case, however, as a missed structure to the southwest of the Main Stope extended the Main Stope orebody for another 100 feet. This became the Main Stope Extension. Through the course of the season, six pockets were hit along this previously hidden structure, and plans to sink the winze were put on hold indefinitely.

May 20–May 22: The mine is opened on May 20, and by the 22nd the first rounds of the year are blasted. Scott Betz's task is to widen the area at the bottom of the Main Stope in order to rig up a hoist for the new shaft. Immediately upon his starting the task, a beautiful, small 14 x 11 x 2½-inch pocket is exposed in the left rib of the tunnel. Several days later, about 12 high-luster rhodochrosite specimens are collected—a great way to start the season! The pocket is no more than 3 feet into an old tunnel wall and only 10 feet below the spot where the great 1966 pocket was discovered. As the pocket was discovered during the full moon on June 1, it is dubbed the Full Moon Pocket.

Thinking the Full Moon Pocket was a fluke, the opposite (right) rib is probed and shot next. As luck would have it, another pocket is almost immediately hit on this side. This, however, is no small pocket. Literally 5 feet below the old Kosnar workings in the Main Stope, it turns out to be one of the largest pockets yet discovered at the mine.

June 12: The first chamber of the new pocket is carefully opened up and collected. One major piece is finally taken out of this chamber that measures 14 inches long. Once this piece is removed, a small opening appears in the back of the pocket, revealing a larger chamber behind.

June 26: The second chamber is breached when Scott, Dean and Bryan carefully split into its edge. Bryan Lees' notes:

> I saw the pocket extension for the first time. It's incredible! It goes up about 4 feet and back about 7 feet. The pocket is chambered with quartz "balls" coating the walls. The opening is large—about 8 inches wide in the largest areas. A few killer rhodochrosites are tucked into the corners—maybe 4 pieces. Pocket is relatively empty. Too bad because there is so much space in there. Volume-wise, it is as big as the Coors Pocket.

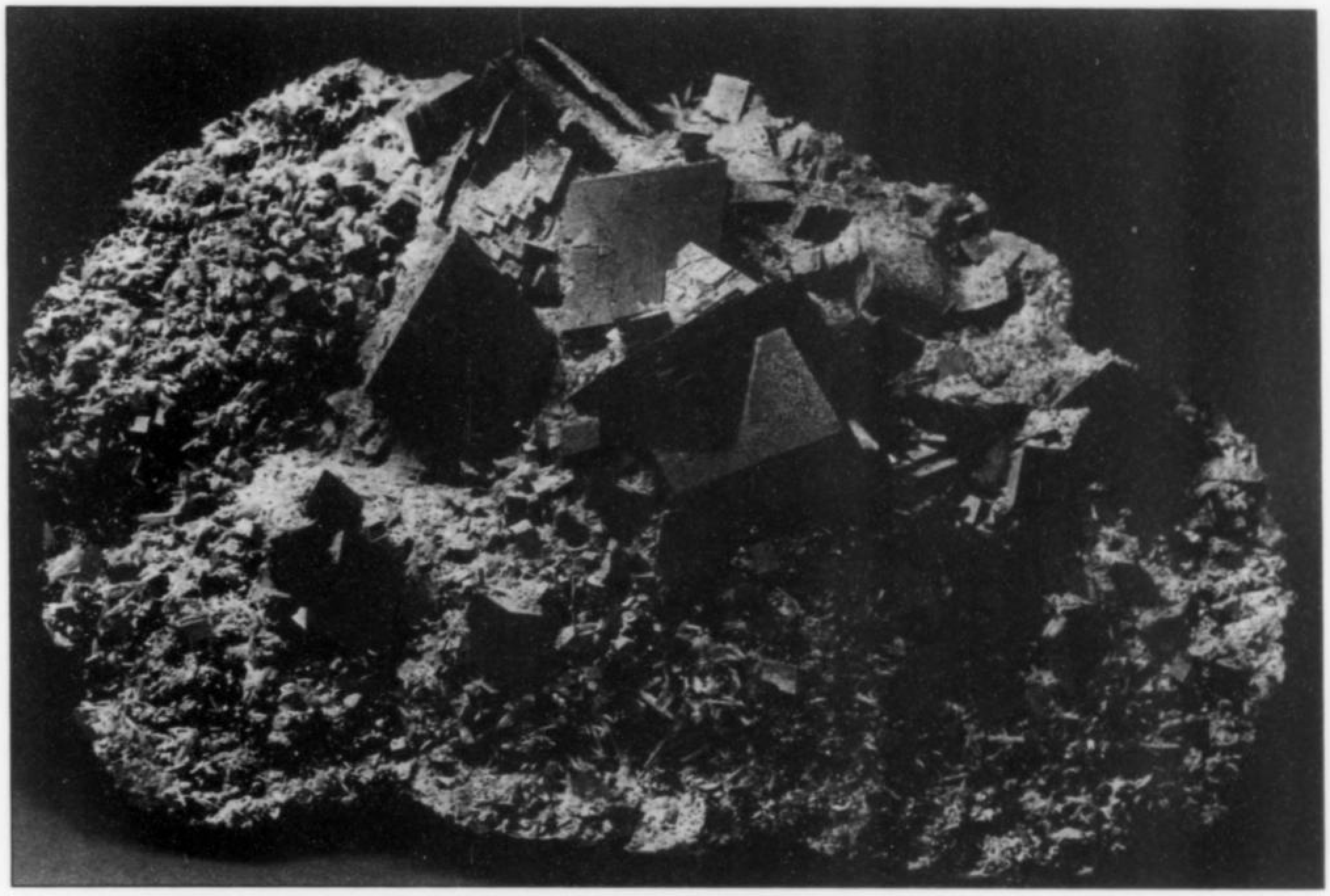
Some of the sprays contain small rhodochrosite crystals. The rhodochrosite quality is outstanding, but the crystals are not plentiful, and most of the pocket is empty. A few 1-inch to 2-inch rhodochrosites are aesthetically perched here and there and, in a couple of spots, scars from larger rhodochrosites dot the walls. These rhodochrosites are found in the bottom of the pocket—they will be reattached to their base plates at the shop.

June 27–August 1: The pocket proves to contain a total of six interconnected chambers. Its discovery date coincides with the blue moon in June, so this one is named the Blue Moon Pocket. It is finally emptied out by August 1. In all, 12 top pieces are removed. These are accompanied by several hundred lesser pieces. Had the pocket been more densely packed with rhodochrosites, it would have turned out to be the most significant Sweet Home discovery ever.

Meanwhile, Rodney and Tony are busy in the Tetrahedrite Stope. A large pocket with heavily damaged rhodochrosites is discovered in July, but in general the Tetrahedrite Stope is not producing anything significant.

After discovery of the Blue Moon Pocket, Dean reviews the mine maps and remaps the area, only to discover that in 1993 the crew had drifted on the wrong southeast Main Stope structure. It turns out that at the drift level of the Main Stope, the vein splits and its two branches parallel each other to the southwest. In 1993, the crew followed the wrong structure! This changes the 1997 mine plan. Instead of putting in the shaft, the crew decides to continue the new southwest drift, now called the Main Stope Extension, and look for more pockets.

August 6 [Discovery of the Hedgehog Pocket]: Just a few feet



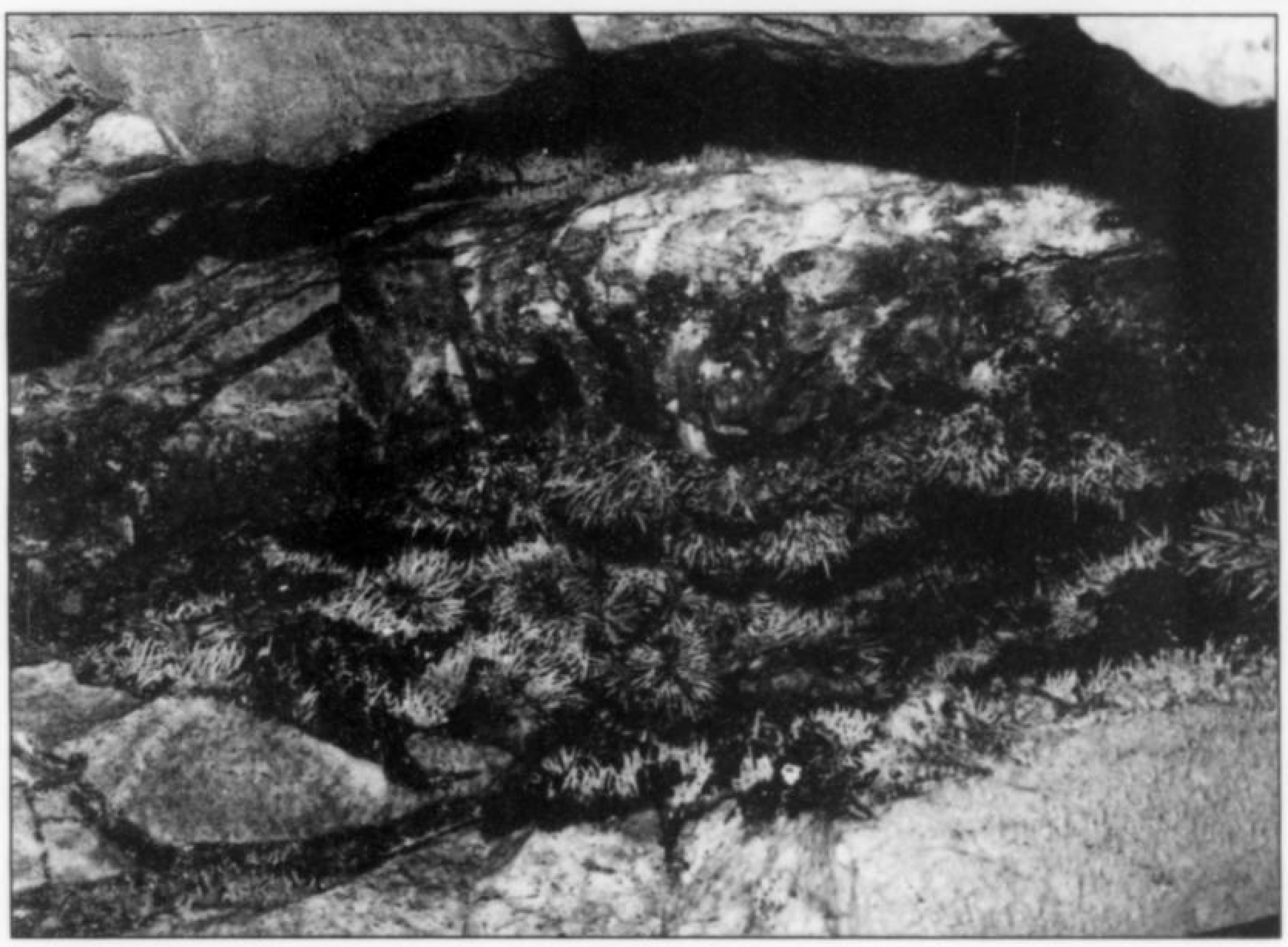


Figure 115. **The rhodochrosite specimen from the Blue Moon Pocket after extraction, trimming and cleaning; 34.5 cm long. Peter Via collection; photo by Bernie Kowalski.**

Figure 116. **View looking straight up into the Blue Moon Pocket. The pocket walls are lined with quartz "balls." Unfortunately, most of the pocket is empty. Still twelve excellent pieces were ultimately recovered. Photo by Bryan Lees.**

beyond the Blue Moon Pocket, a probe hole intersects another pocket.

August 7: The new pocket opened up (Fig. 123) is outstanding. It resembles 1992's Cash Flow Pocket but the rhodochrosites are much more lustrous. The pocket goes into the face at least 5 feet and seems to be about 3 feet high and up to 12 inches wide [eventually, the pocket will extend to 10 feet]. Most of the opening is constricted and choked by large rhodochrosite-coated breccia fragments, leaving scant millimeters between them for rhodochrosites to form.

August 20: During the past week, hundreds of specimens have been collected, from thumbnails to plates measuring 2 feet across. The good thumbnails have ¼-inch to ½-inch rhodochrosites perched aesthetically on 1 to 1½-inch quartz needles. The good small cabinet-sized pieces have a quartz needle coating on both sides of the specimens, with the densest rhodochrosite coverage favoring one side. Some plates have pyrite crystals to ½-inch and hübnerite crystals to 2 inches.

September 16: During the last three weeks, several large plates were collected. They measure 2 x 1½-feet and are very heavy. They are also coated on both sides with crystals. Collecting these was physically difficult as they weigh up to 200 pounds apiece, but most were collected with little to no damage. Dean, Scott and Bryan rotated as "head" collector, as each in turn became exhausted taking these great pieces out.

Many of the specimens from this pocket have a rounded quartz

Figure 117. Rhodochrosite wedged inside the Blue Moon Pocket. It required about a day to remove the specimen without damage, using small diamond cutting and grinding tools. Photo by Byran Lees.

Figure 118. Rhodochrosite, Blue Moon Pocket, Main Stope Extension; the crystal measures 5.5 cm long. Sweet Home Rhodo, Inc. collection; photo by Harold and Erica Van Pelt.

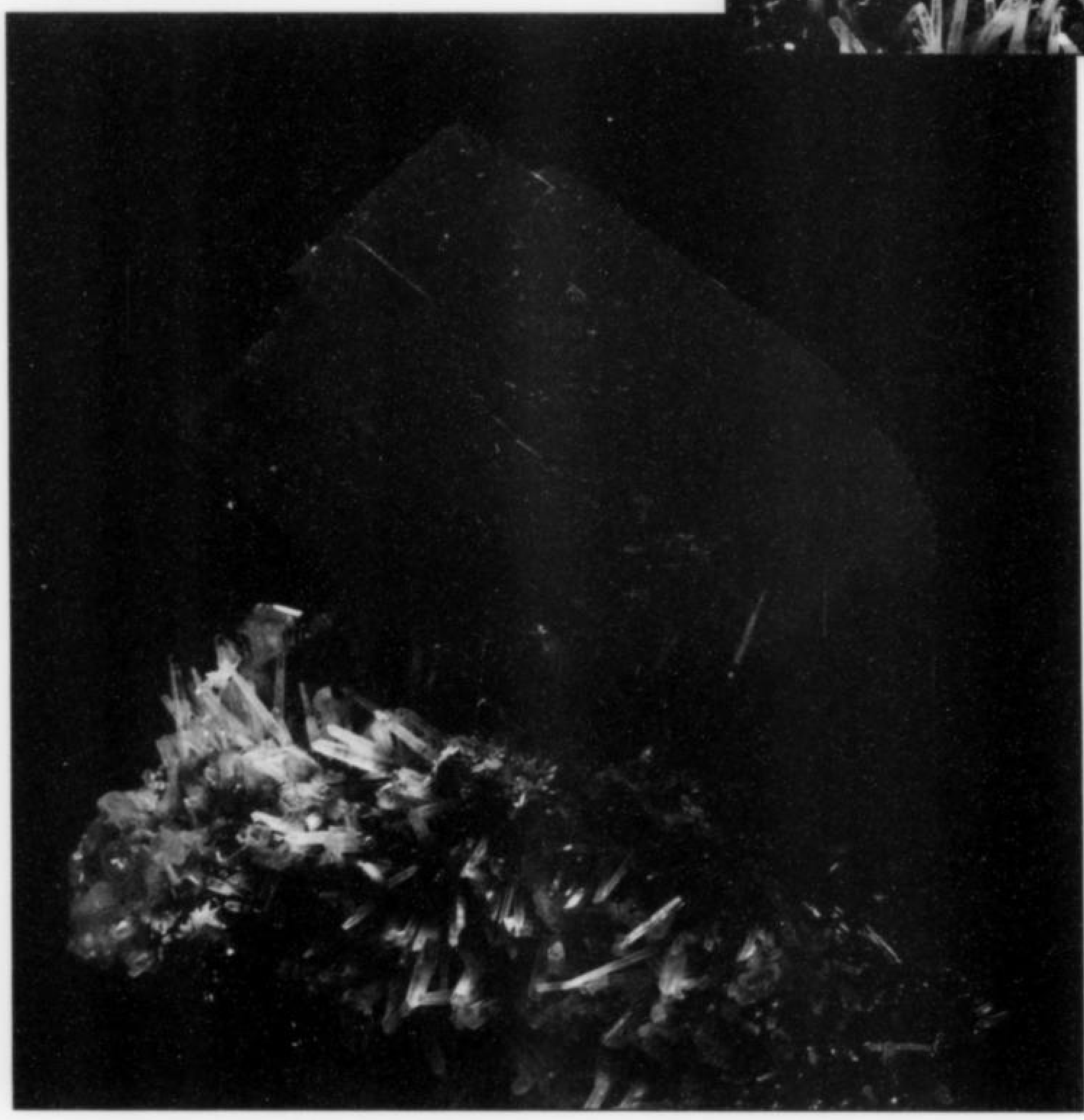


Figure 119. Rhodochrosite, 16 cm, Blue Moon Pocket, Main Stope Extension; this is the specimen shown *in situ* in Figure 117. University of British Columbia collection; photo by Jeff Scovil.

Figure 120. **Most of the rhodochrosite crystals in the Blue Moon Pocket were growing near the pocket margin, making clean collecting difficult. Here, a small chipping tool is used to break matrix away from the opposite wall, freeing the crystal terminations. Photo by Bryan Lees.**

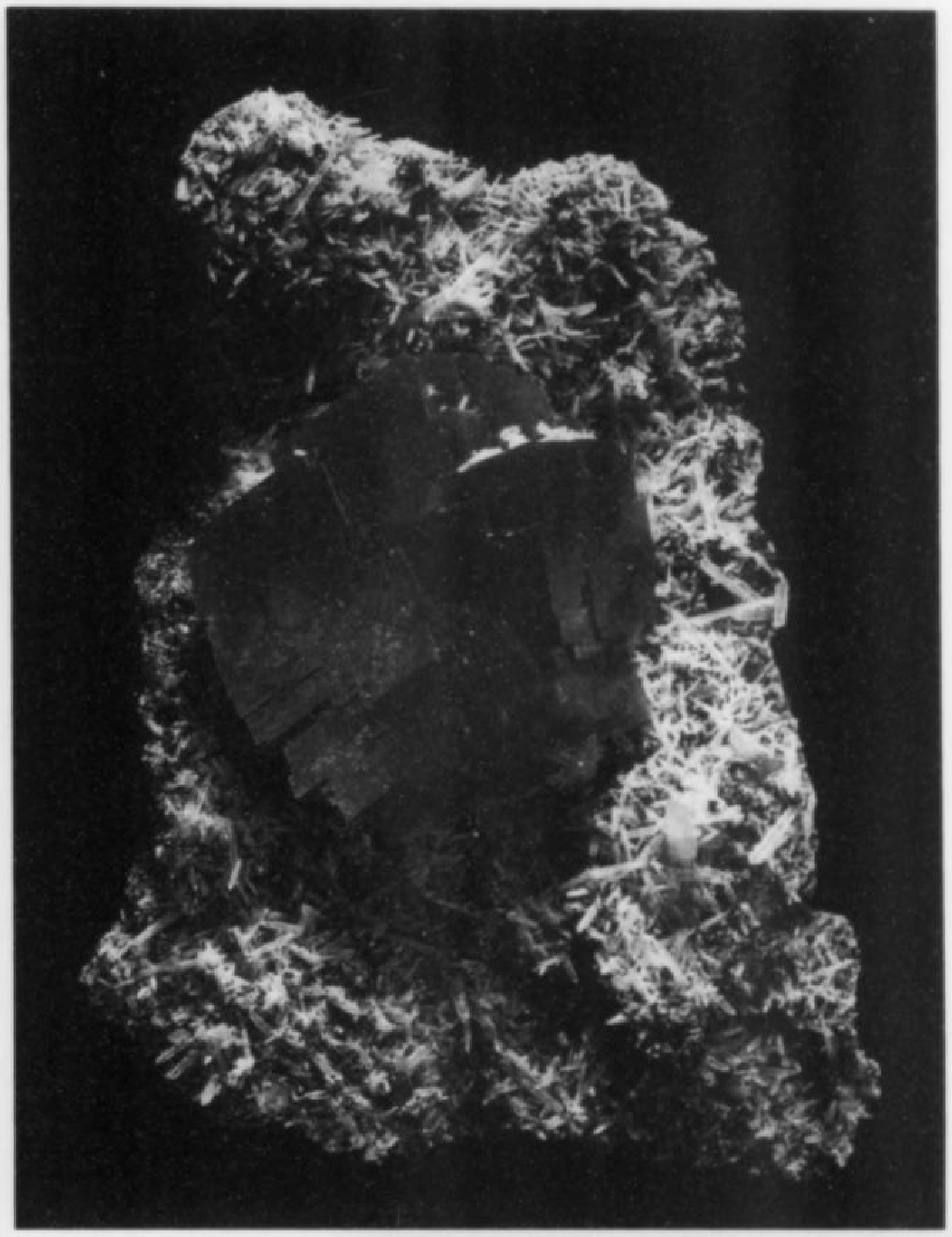


Figure 121. (above) **The Searchlight Rhodochrosite, Blue Moon Pocket, Main Stope Extension, 19.3 cm tall. Jack Halpern collection; Jeff Scovil photo.**

Figure 122. **Galena coated by chalcopyrite with quartz, Blue Moon Pocket, Main Stope Extension, 2.7 cm high. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

ridge radiating from their sides which makes them resemble hedgehogs. Of course, this prompts the crew to call it the "Hedgehog Pocket." About 1,500 pieces are collected. It seems that every square inch of the pocket contained specimens. Not all are great; many of the pieces are single small crystals. People attending the Tucson Gem and Mineral Show in February, 1997 enjoyed seeing several of the Hedgehog pieces on display there.

While the Hedgehog Pocket is being collected, Rodney and Tony are continuing their efforts in the Tetrahedrite Stope. No discoveries are made by mid-September and the equipment is finally pulled out of the stope. Their next task will be to drive an extension of the Tetrahedrite Drift from the base of the stope to the southwest.

September 17 [Discovery of the Butterfly Pocket]: By the end of the Denver Gem and Mineral Show, Scott and Dean are busy

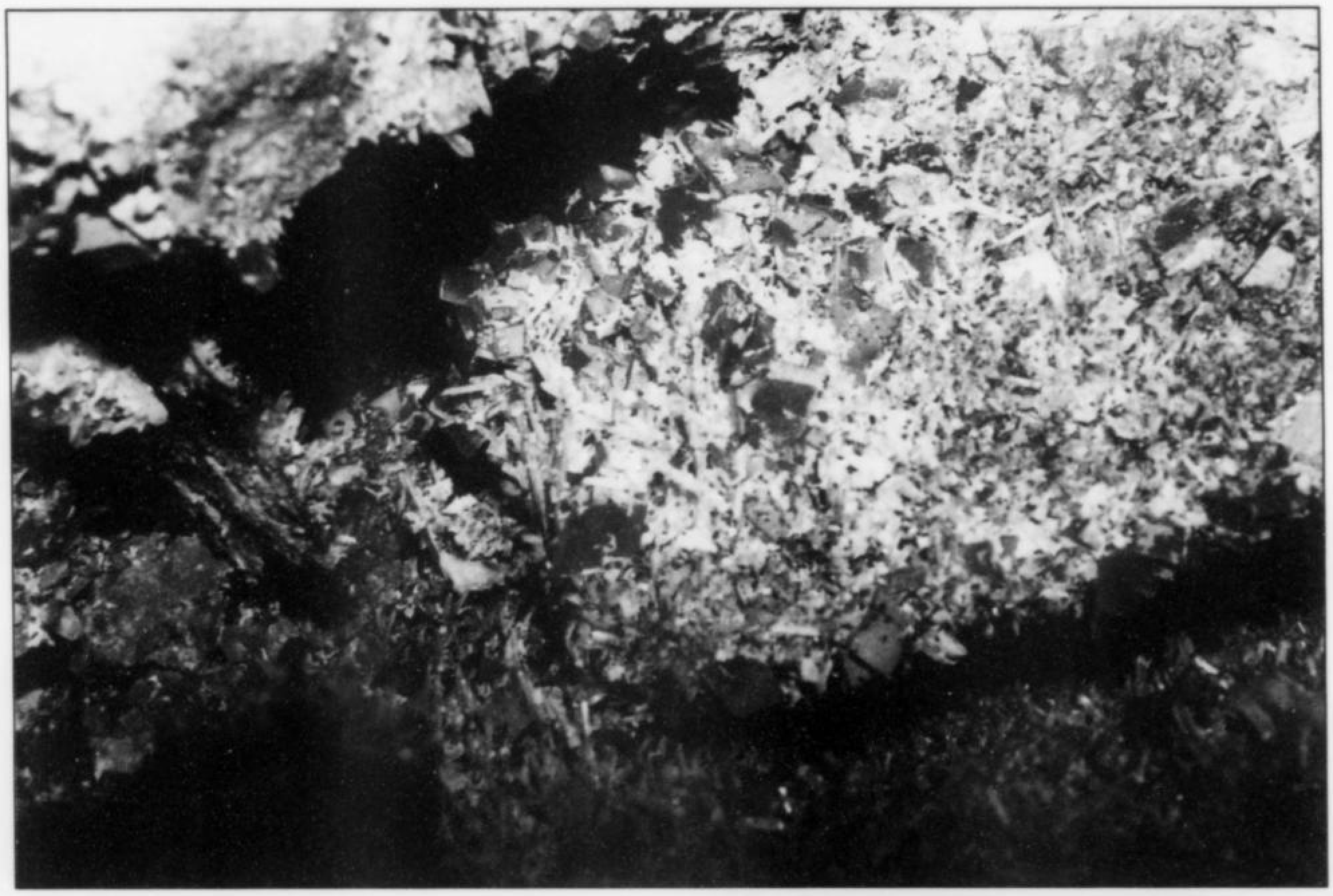


Figure 123. View looking into the Hedgehog Pocket in August, 1996. The field of view is approximately 7 inches wide. This pocket was filled with breccia fragments covered with small rhodochrosite crystals. Photo by Albert Lees.

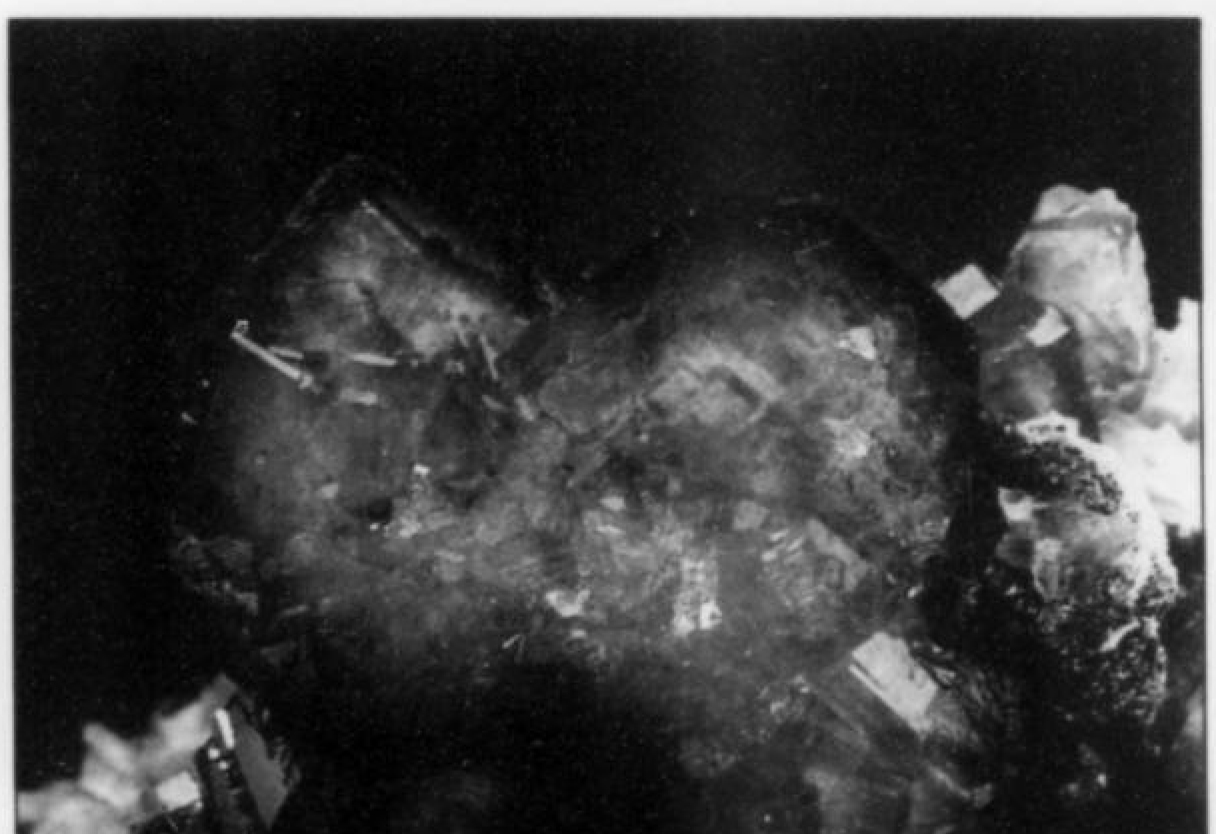


Figure 124. Fluorite, Blue Moon Pocket, Main Stope Extension, 3.1 cm wide. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.

Figure 125. Bryan Lees *(left)* uses a diamond chainsaw to peel rhodochrosite plates out of the Hedgehog Pocket. Photo by Albert Lees.

Figure 126. A 202-pound plate from the Hedgehog Pocket is washed for viewing. Photo by Bryan Lees.

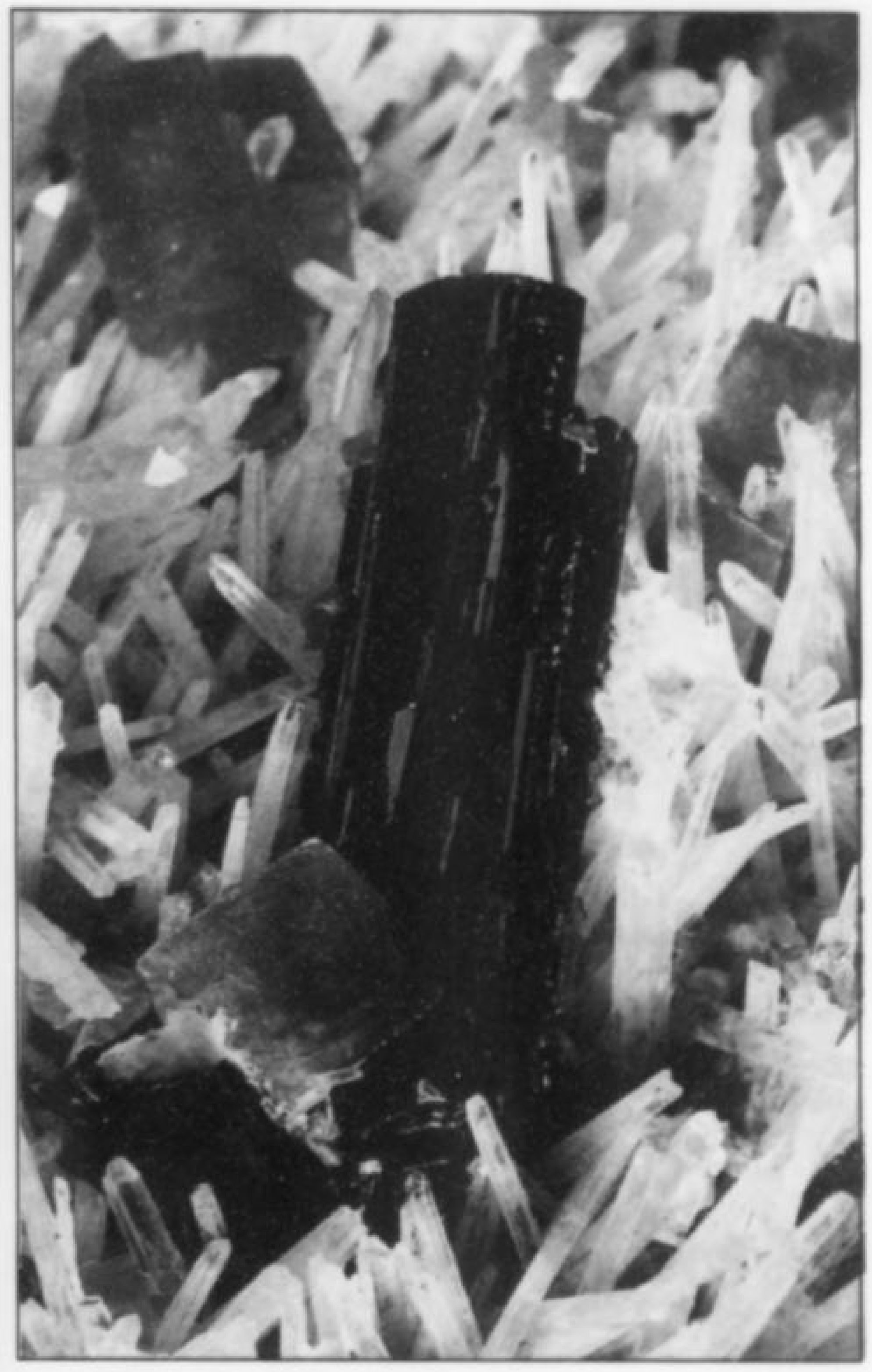


Figure 127. Hübnerite (3.5 cm) and rhodochrosite on quartz, Hedgehog Pocket, Main Stope Extension. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.

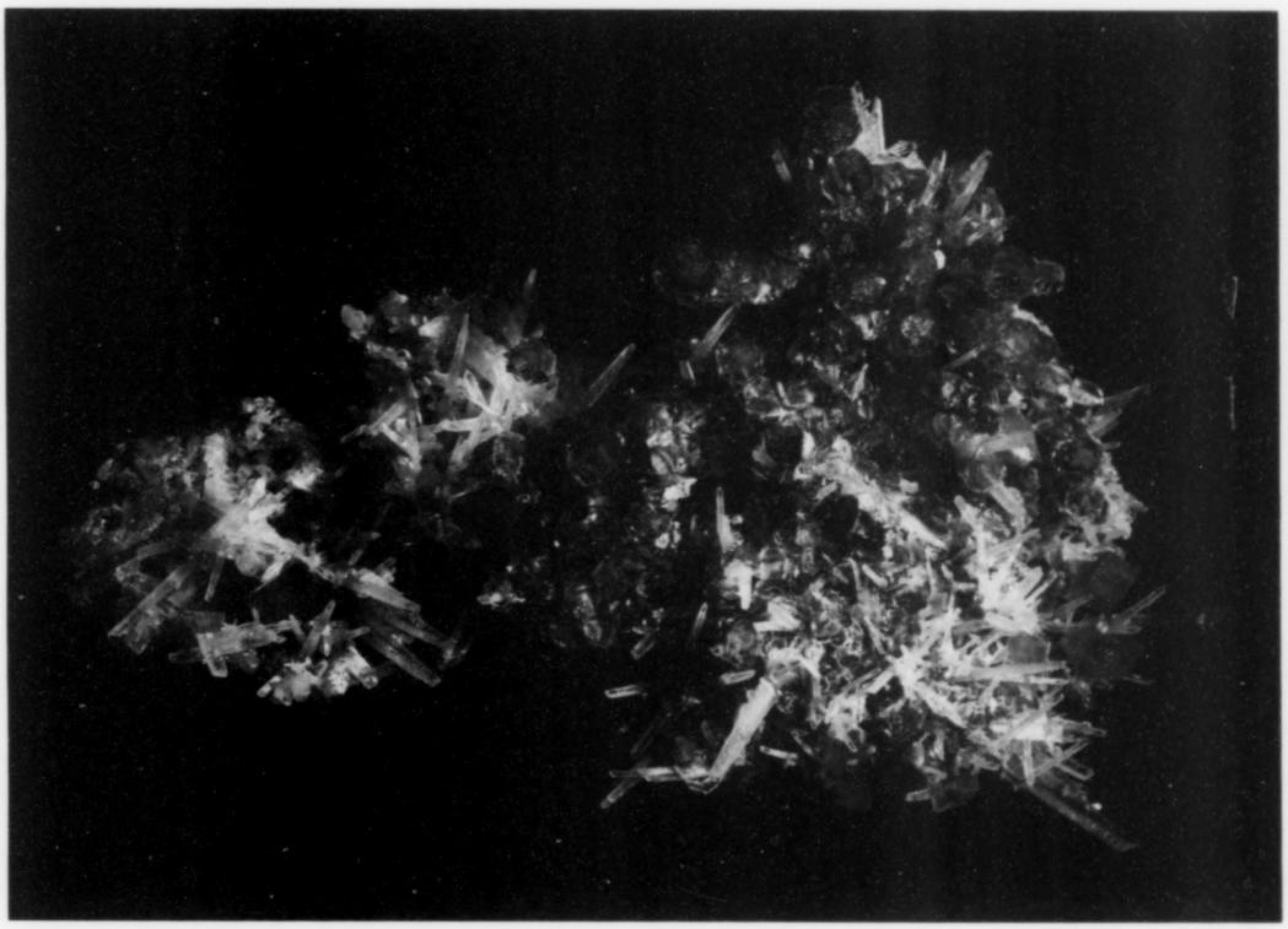


Figure 128. Fluorite and rhodochrosite on quartz, Hedgehog Pocket, Main Stope Extension, 10.3 cm wide. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.

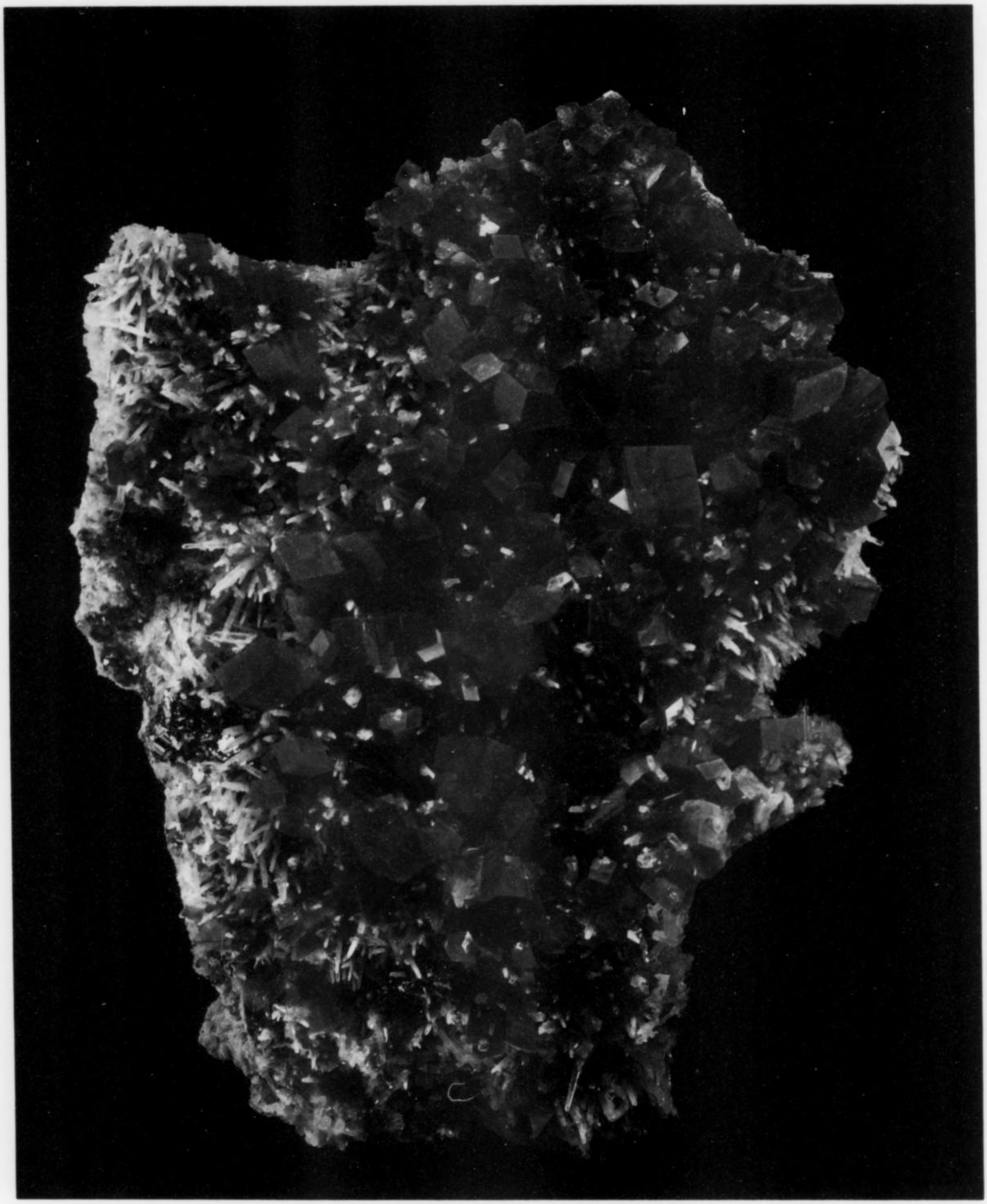


Figure 129. **Rhodochrosite and fluorite on quartz, Hedgehog Pocket, Main Stope Extension, 17.5 cm wide. Sweet Home Rhodo, Inc. collection; Harold and Erica Van Pelt photo.**

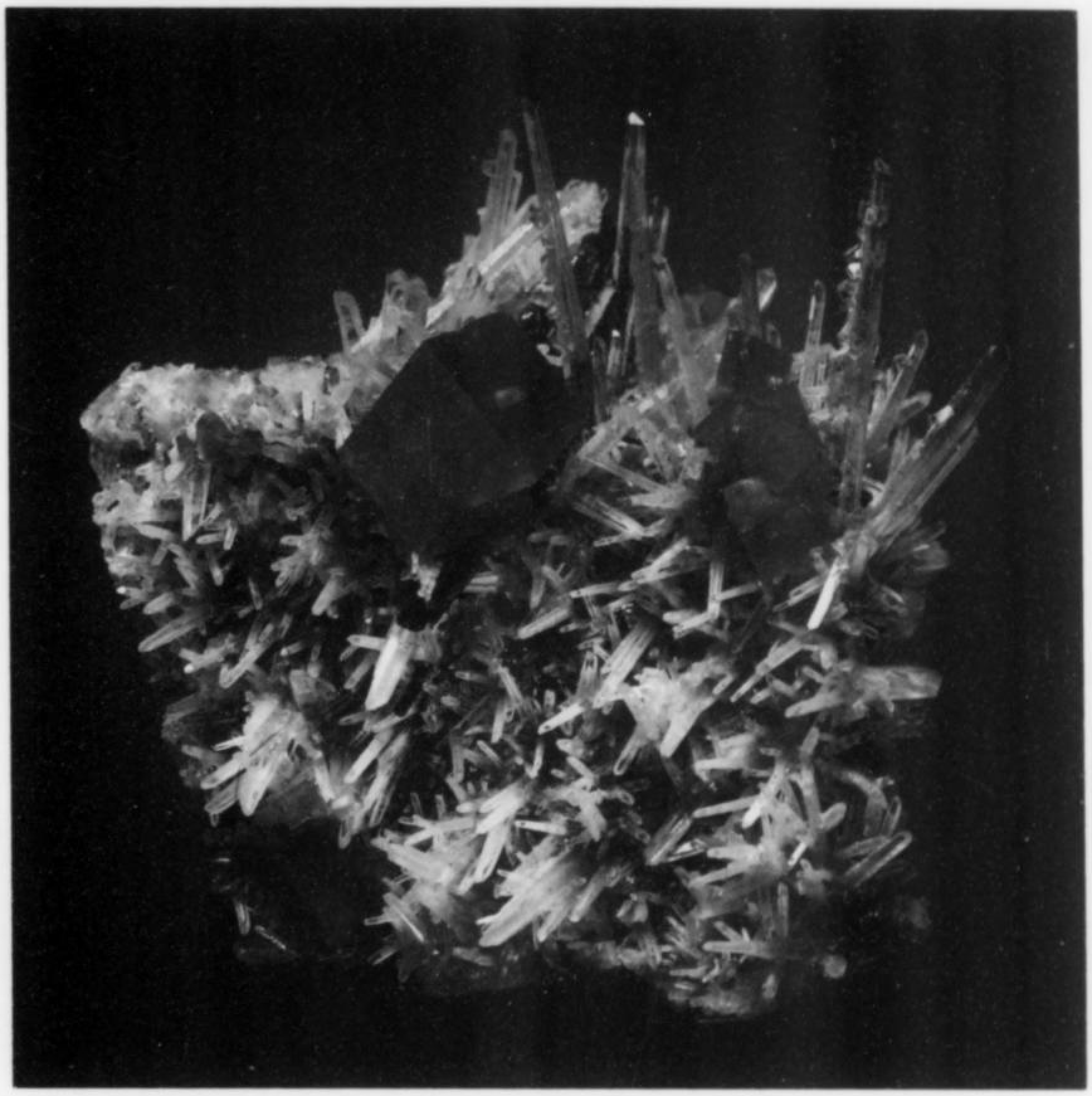


Figure 130. **Rhodochrosite on quartz, Hedgehog Pocket, Main Stope Extension, 7.5 cm wide. Sweet Home Rhodo, Inc. collection; Harold and Erica Van Pelt photo.**

driving the Main Stope Extension drift southwest past the Hedgehog Pocket. It does not take long for lightning to strike again. On the day after the show, another pocket is found. Although not as large as the last one, the new pocket contains some crystals to 3 inches across.

September 19: A large rhodochrosite specimen takes shape inside the pocket. Fragments of rhodochrosite $1^1/_2$ x 3 inches are coming out of the bottom of the pocket.

September 23: Scott, Dean and Bryan cut a plate off the vug wall containing the scars of two interlocking 3-inch rhodochrosite rhombs. The pocket is now cleaned out and its empty interior measures 3 inches wide by 18 inches high by 18 inches deep.

Once back at the shop, the large rhodochrosite crystals are quickly reassembled onto the scars and the "Butterfly" takes shape. This piece is one of the best ever discovered. The Butterfly Pocket also contained beautiful $^1/_4$ to $^1/_2$-inch purple dodecahedral fluorites—several of these coat the "Butterfly" specimen (Fig. 135).

Those attending the Tucson Gem and Mineral Show in February, 1997 were able to view this amazing specimen when it was showcased next to the famous Bolivian phosphophyllite (see "What's New in Minerals," vol. 28, p. 213). Not many pieces were removed from this pocket, but once again the miners were reminded what beauty could come from such a small pocket.

October 5: Along the Main Stope Extension, Scott and Dean hit another pocket. This one is mostly empty and measures 6 feet deep by 3 feet high by 1 to 4 inches wide. Inside, there is one very large rhodochrosite: 5 inches on a side, rivaling the Alma King. Unfortunately, the crystal is heavily fractured and falls apart upon extraction. Still, the remaining specimen is impressive and it receives the name "Mini King."

In the Tetrahedrite Drift, Rodney and Tony continue to drift to the southeast with no results. But the structure is still strong, so it is decided to continue in this direction.

October 17: The Main Stope Extension vein widens and a probe hole intersects a void which drains water all weekend. This is a great indicator for pockets. On the 22nd, Scott shoots a short round into this area and discovers a void in the upper corner of the drift. The void is packed full of clay. Dean and Scott wash this material for the rest of the day to open up the pocket. Once cleared, the pocket contents come into view.

Bryan Lees' notes from October 24 to 30:

> I arrived in the morning and saw the new pocket. Scott and Dean had it opened up to 4 feet across the back. The pocket is full of clay and (what looks like) palygorskite. The clay has to be heavily flushed out to see the rhodochrosites.
>
> . . . The rhodochrosites are $^3/_4$ to $1^1/_2$ inches, large, but most are contacted due to the tightness of the pocket. By quitting time, a small 8 x 8 x 3-inch wide void opens up and contains uncontacted rhodochrosites to $1^1/_2$ inches on wallrock (Fig. 139).
>
> . . . The rhodochrosites are of a stepped crystal habit and have good luster. They are on a matrix of quartz and sulfides. Associations include lustrous galena ($^3/_8$-inch), lustrous chalcopyrite ($^3/_8$-inch), lustrous tetrahedrite ($^3/_8$-inch) and cubic purple fluorite ($^1/_4$-inch).
>
> . . . There is so much clay filling that the minerals are difficult to see until the pieces are brought back to the shop and washed. The pocket is sectioned off into chambers, as opposed to some which resemble open cracks. The chambers are created by quartz infilling around breccia fragments thus

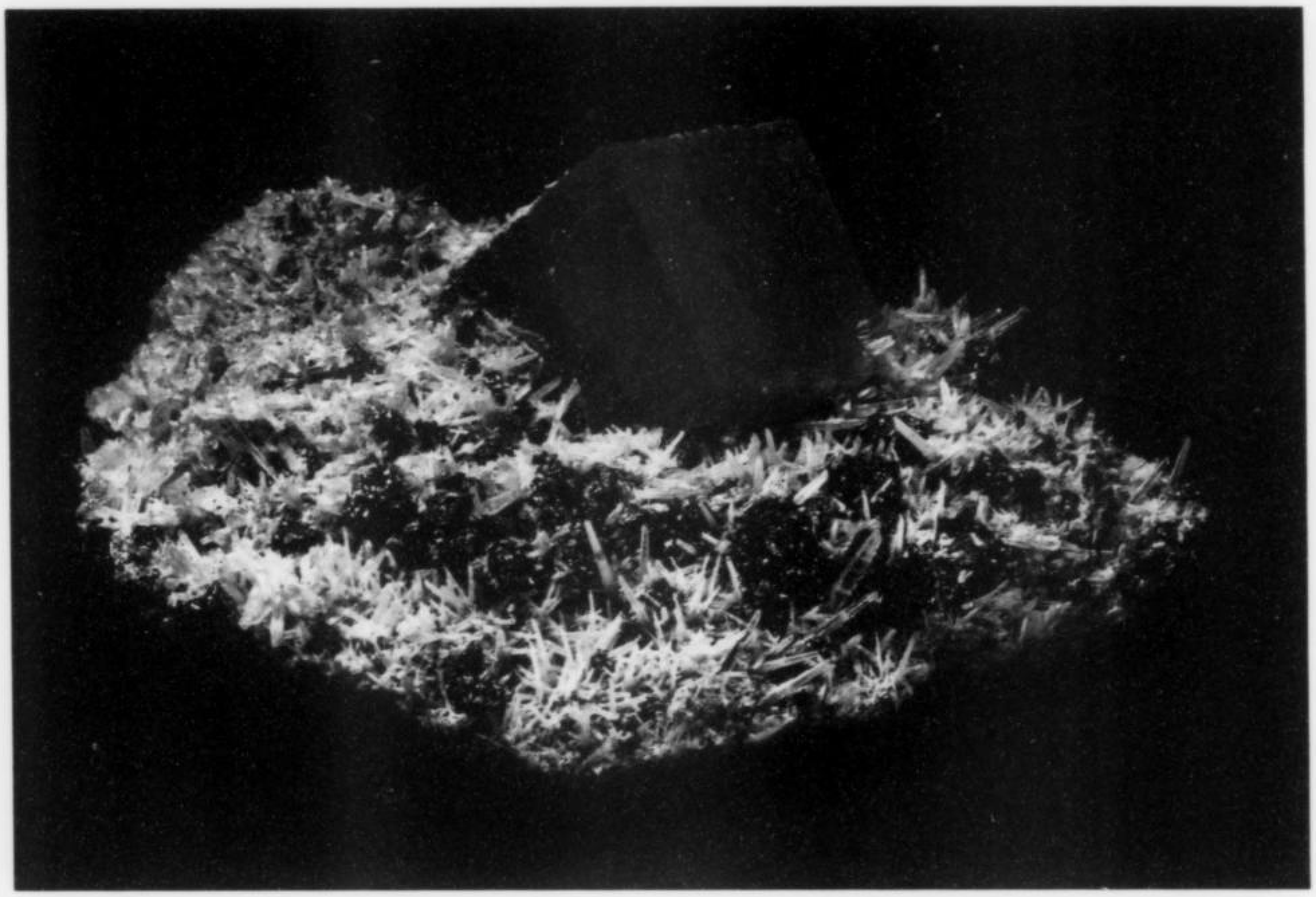


Figure 131. **Rhodochrosite on quartz and sulfides, Butterfly Pocket, Main Stope Extension: the crystal from Figure 132 after extraction and cleaning. Joe Freilich collection; Geoffrey Wheeler photo.**

Figure 132. **Miner Rodney Orten peers into the Butterfly Pocket. A perfect 5.1 cm rhodochrosite crystal stares back. Photo by Bryan Lees.**

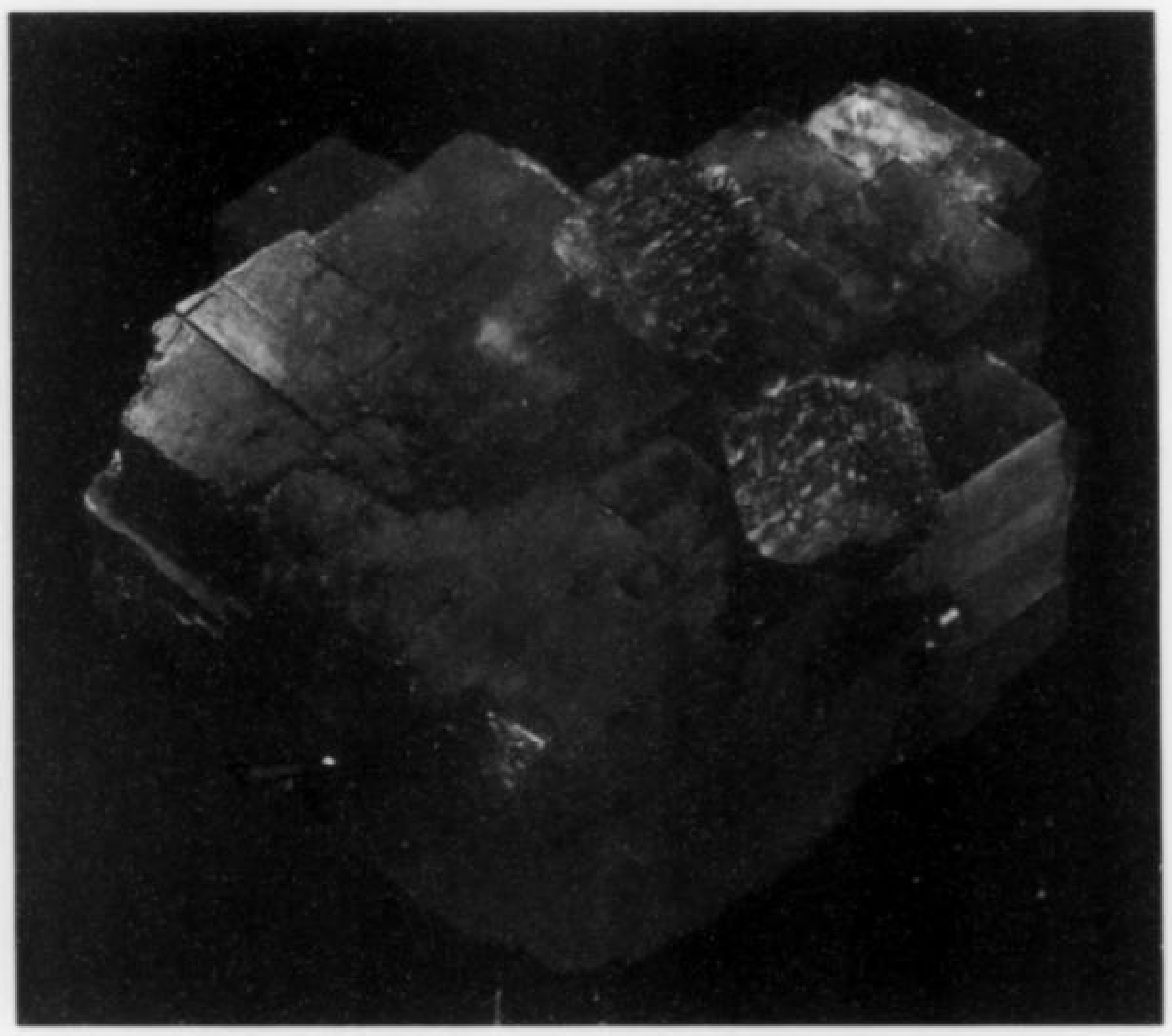


Figure 133. **Fluorite on rhodochrosite, Clay Pocket, Main Stope Extension, 3.7 cm wide. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.**

tightly sealing the pocket and discouraging very large crystal growth. Also, there has been much pocket movement through time, destroying many of the crystals.

. . . It's 15 degrees outside and everything is starting to freeze up.

. . . On October 28, we collected an open pocket area. Four killers were removed. One floater group contains about 4 perfect crystals to 1¾ inches. They are isolated on matrix and extremely aesthetic. The other pieces are smaller versions of this one. Some contain beautiful blue-purple fluorite cubes to ¼-inch.

. . . On October 30, we finished cleaning out most of the pocket. It is now tight and shows no indication of opening up again. We collect several small, excellent pieces including some with hübnerite and fluorite.

Back at the shop Robert Lorda and Bill Hawes wash these specimens to reveal one of the season's finest pieces—a plate

Figure 134. **The "Golf Ball," fluorite on quartz with sulfides, including tetrahedrite coated with covellite, Mini King Pocket, Main Stope Extension. The crystal is 4.8 cm wide. Sweet Home Rhodo, Inc. collection; Harold and Erica Van Pelt photo.**

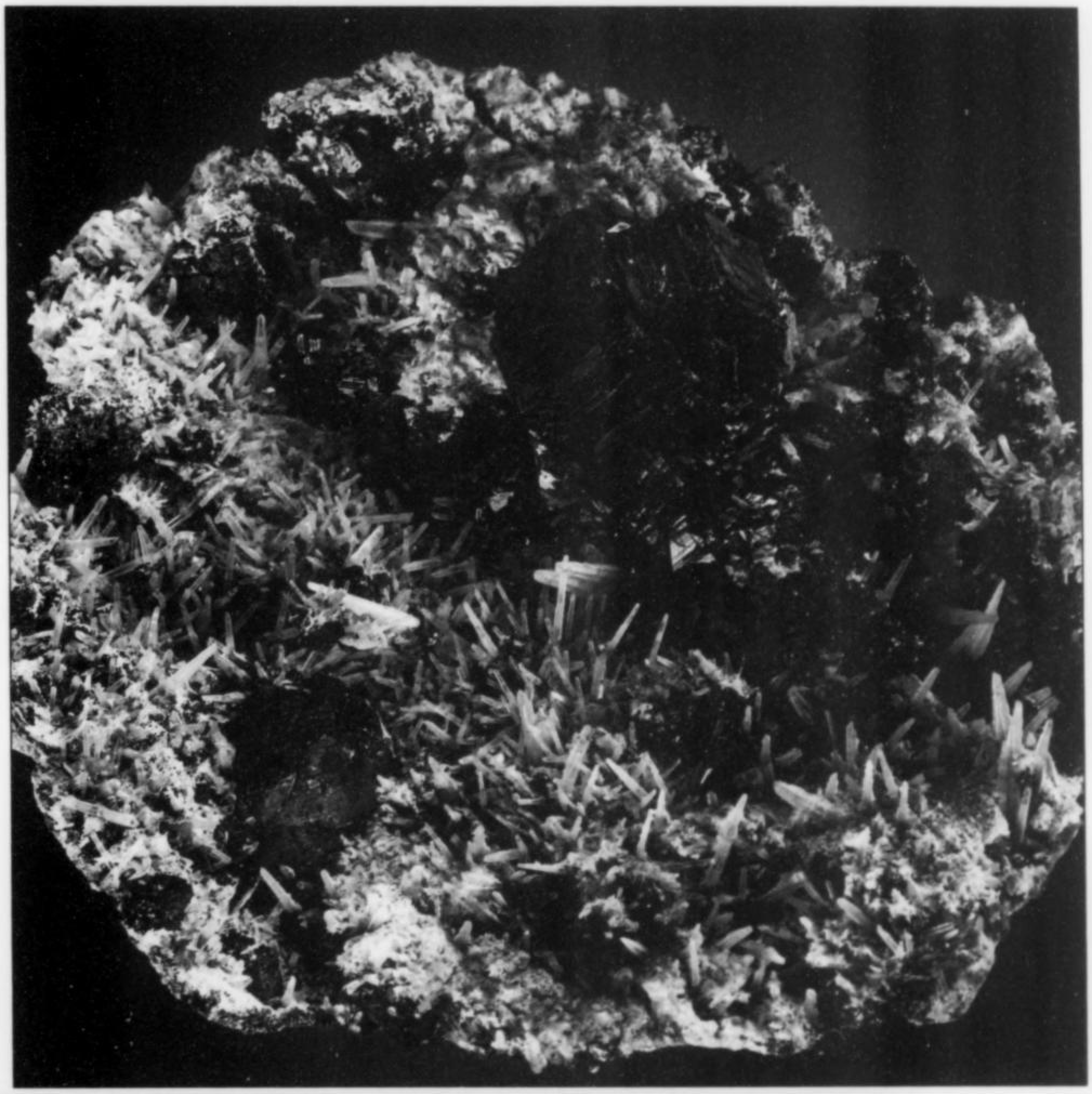


Figure 135. **The "Butterfly" rhodochrosite, Butterfly Pocket, Main Stope Extension; the crystals measure 9 cm across. James Horner collection; Harold and Erica Van Pelt photo.**

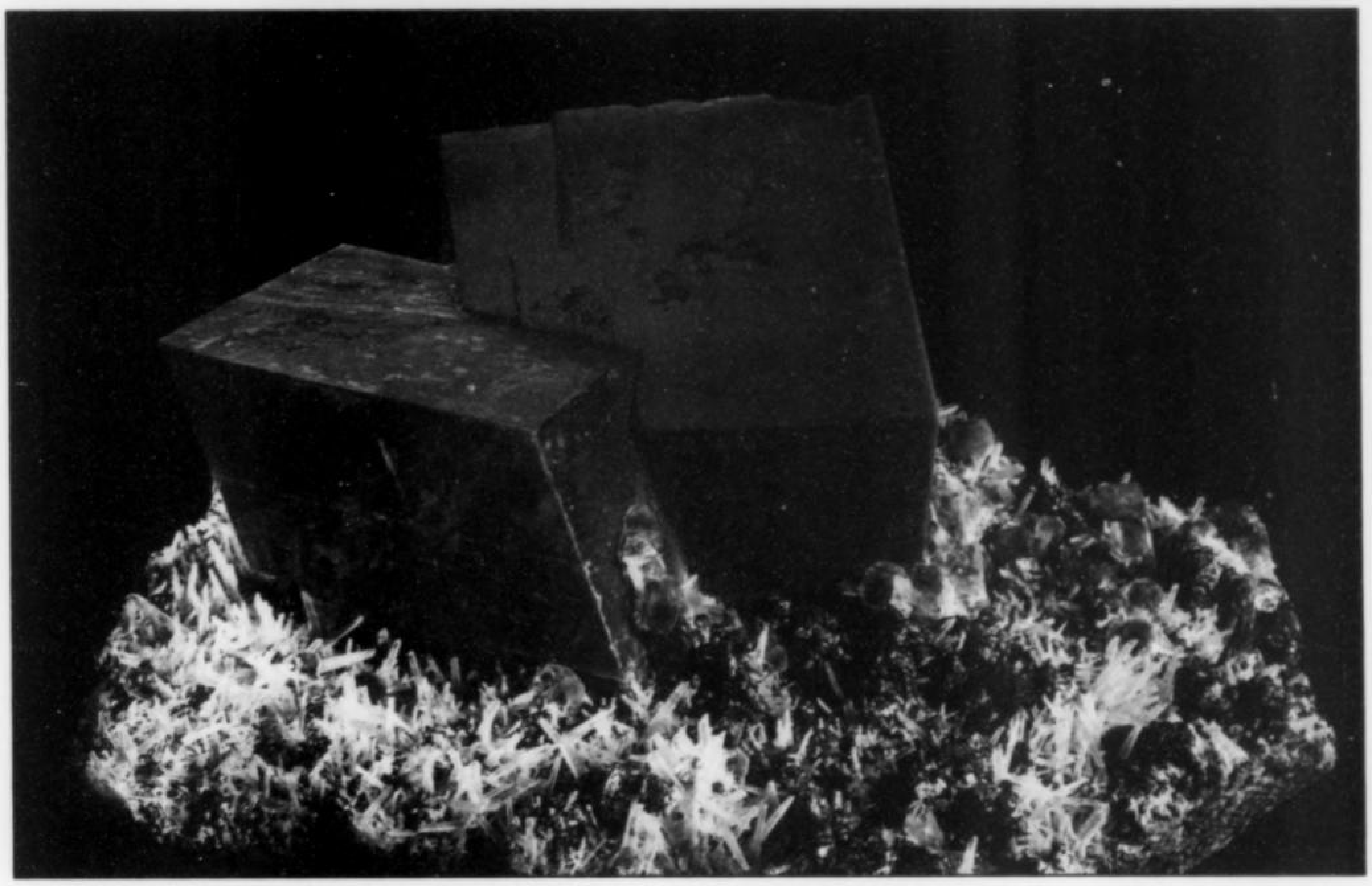


Figure 136. **Rhodochrosite with fluorite on quartz, Clay Pocket, Main Stope Extension, 7.8 cm wide. Sweet Home Rhodo, Inc. collection; Harold and Erica Van Pelt photo.**

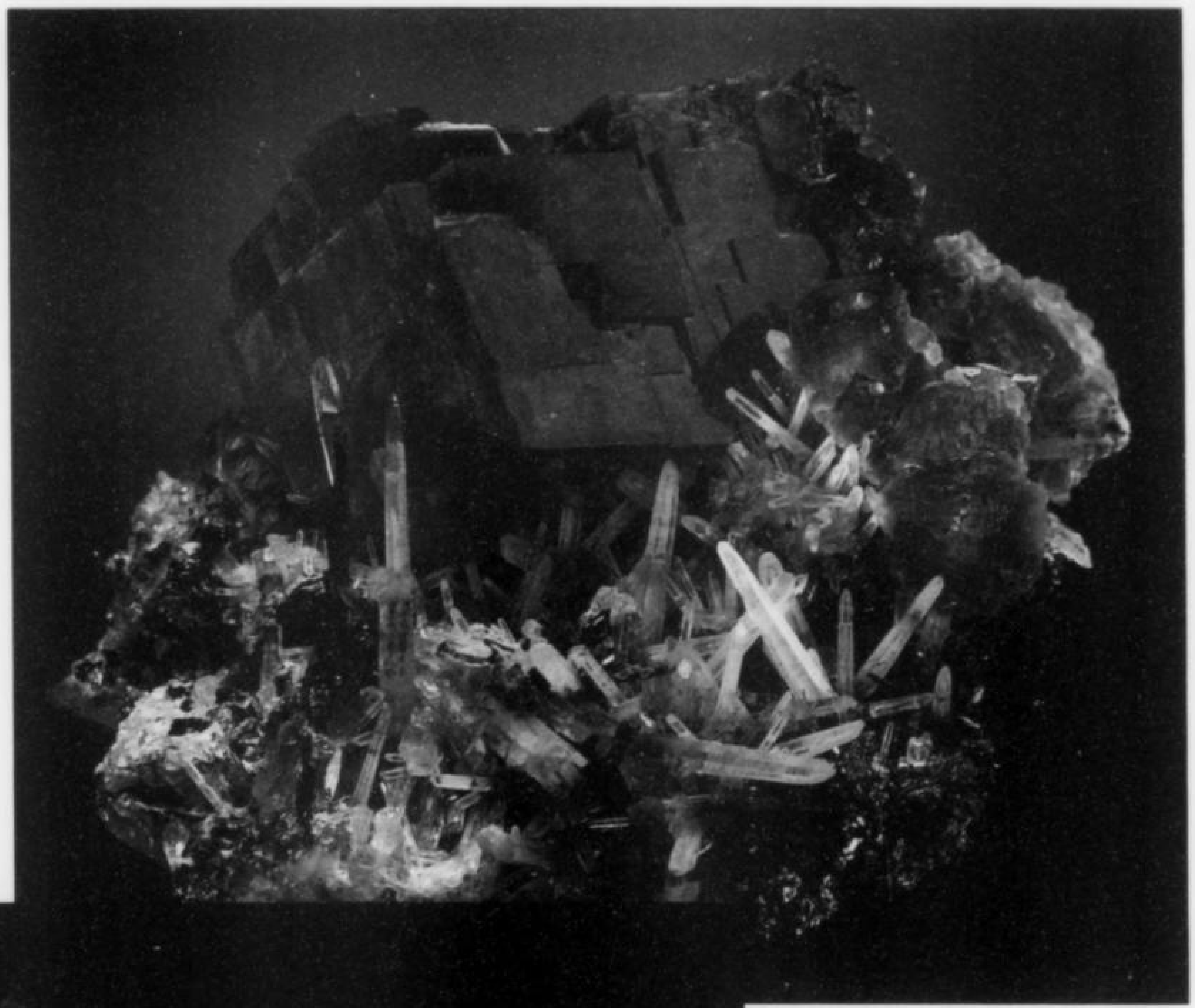


Figure 137. **The "Garden" rhodochrosite with fluorite and hübnerite on quartz, Clay Pocket, Main Stope Extension, 21.8 cm tall. Sweet Home Rhodo, Inc. collection; Harold and Erica Van Pelt photo.**

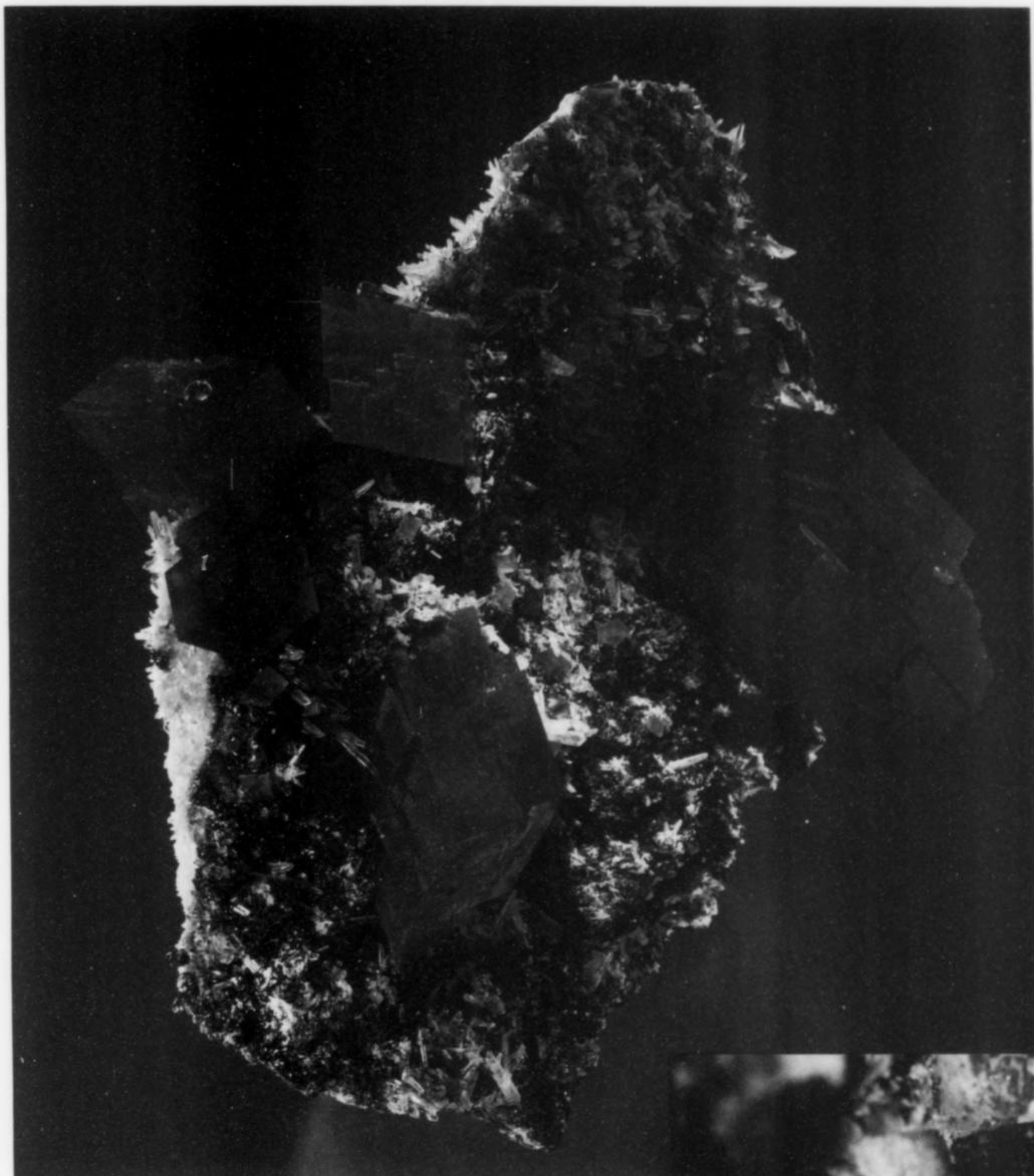


Figure 138. **Rhodochrosite on quartz and sulfides, Clay Pocket, Main Stope Extension: the specimen from Figure 139 after extraction and cleaning; 13.5 cm tall. John Lucking collection; Harold and Erica Van Pelt photo.**

Figure 139. **View looking into the Clay Pocket. The pocket is packed with clay and palygorskite. Rhodochrosite crystals measure about 3.5 cm. Photo by Bryan Lees.**

measuring 8 inches across containing 1¼-inch rhodochrosites with multiple hübnerites and small fluorites (Fig. 137). Because these plates were so hard to see through the clay, it is decided to call this the "Clay Pocket." The overall pocket dimensions were about 4 feet deep by 3 feet high by 1 to 2 inches wide.

In the Tetrahedrite Drift, the familiar trend is continuing—no pockets. The drift is discontinued and a series of small raises are put in during the rest of the mining season. Unfortunately, nothing is found and this area of the mine is permanently shut down.

Figure 140. **The Coors Pocket reconstruction is completely disassembled and each individual plate is cleaned one last time. Photo by Bryan Lees.**

Figures 141. **Denise Patton and Bill Hawes review the completed Coors Pocket reconstruction. Over 3,000 individual specimens make up the 8 foot by 7 foot pocket. It took three people 20 months to complete. Photo by Bryan Lees.**

Figure 142. **The completed Coors Pocket exhibit, renamed the "Crystal Wall" in June, 1997, as it now looks at the Denver Museum of Natural History. Museum staff worked for over 12 months to recreate the underground environment of the Sweet Home mine. No detail was spared to give the museum visitor a realistic underground experience. Photo by Rick Wicker.**

The mine is closed at the end of November. Five great pockets were discovered—the Full Moon, Blue Moon, Hedgehog, Butterfly and Clay. With this year's success in the Main Stope Extension, there is little doubt that there will be another season.

Coinciding with the mine closure, the Coors Pocket reconstruction work is completed at the Collector's Edge facility in Golden. The Pocket is carefully dismantled and transported to the Denver Museum of Natural History, where work immediately begins to reassemble and incorporate it into the underground tunnel simulation work already completed by the Museum staff.

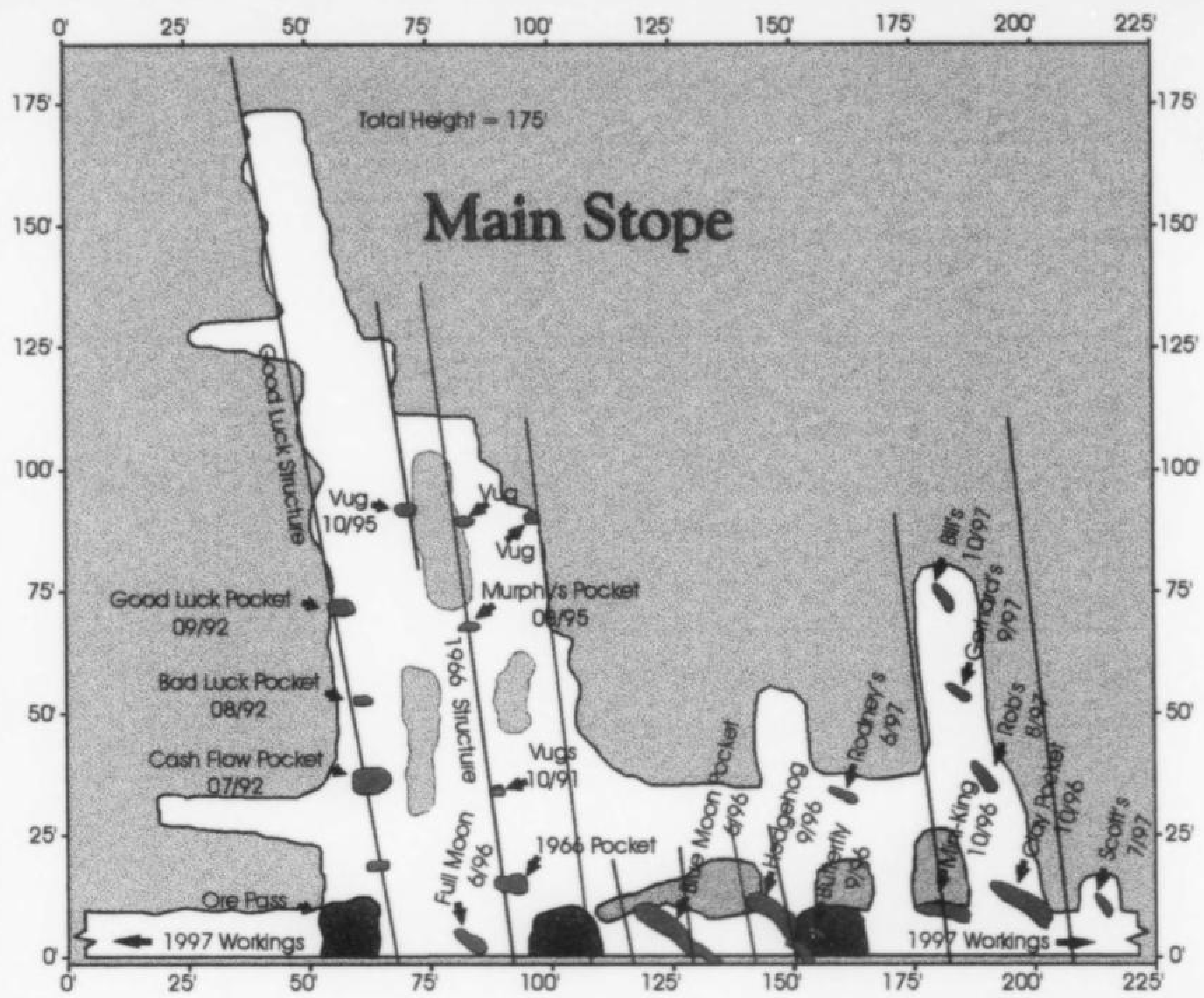


Figure 143. **Section of the Main Stope, looking east, in 1997. Graphics by Bill Tanaka and Bryan Lees.**

Scale in Feet

THE 1997 SEASON

Just before the commencement of mining operations for the 1997 season, a major event in the life of the Sweet Home project occurred. The Coors Pocket (now called the *Rhodochrosite Crystal Wall* by the Denver Museum of Natural History) was completed and ready for public debut. During May, several special previews and grand opening events occurred. On May 29, the grand opening for the general public took place. The exhibit is being hailed as one of the finest, most authentic pocket reconstruction exhibits in the world. For additional reading on the subject, see Jack Murphy's article, "Sweet Home mine rhodochrosite wall at the Denver Museum of Natural History" (*Rocks and Minerals*, vol. 72, no. 4, p. 240), and Bob Jones' articles, "The wall" (*Rock and Gem*, vol. 27, no. 8, p. 12) and "Denver's Wall of Rhodochrosite" (*Rock and Gem*, vol. 27, no. 11, p. 20). If one finds one's self in Denver with a few hours to kill, viewing this exhibit is a must.

In June, another exciting event occurred. The Governor of Colorado, Roy Romer, chose to present a gift featuring rhodochrosite to each of the Summit of Eight leaders during their international conference in Colorado. A base made of Colorado marble, flagstone and glass highlighted a Sweet Home mine rhodochrosite specimen. One of these was presented to each of the eight heads of state as a gift from the People of Colorado.

With the successes of the 1996 season, it was simple to put together a mine plan for 1997. Each pocket hit in 1996 occurred at the intersection between the Main Stope Extension structure and an east-west structure, a by-now-familiar phenomenon (see "Geology of the Sweet Home Mine," this issue). As usual, these intersections created vertical target zones and, therefore, the Sweet Homers' task in 1997 was to raise vertically above each of the 1996 finds.

The 1997 crew was identical to the one in 1996. By June 1, the mine was re-opened. The first task was to extend the Main Stope Extension several more rounds to see if the 1996 pocket trend

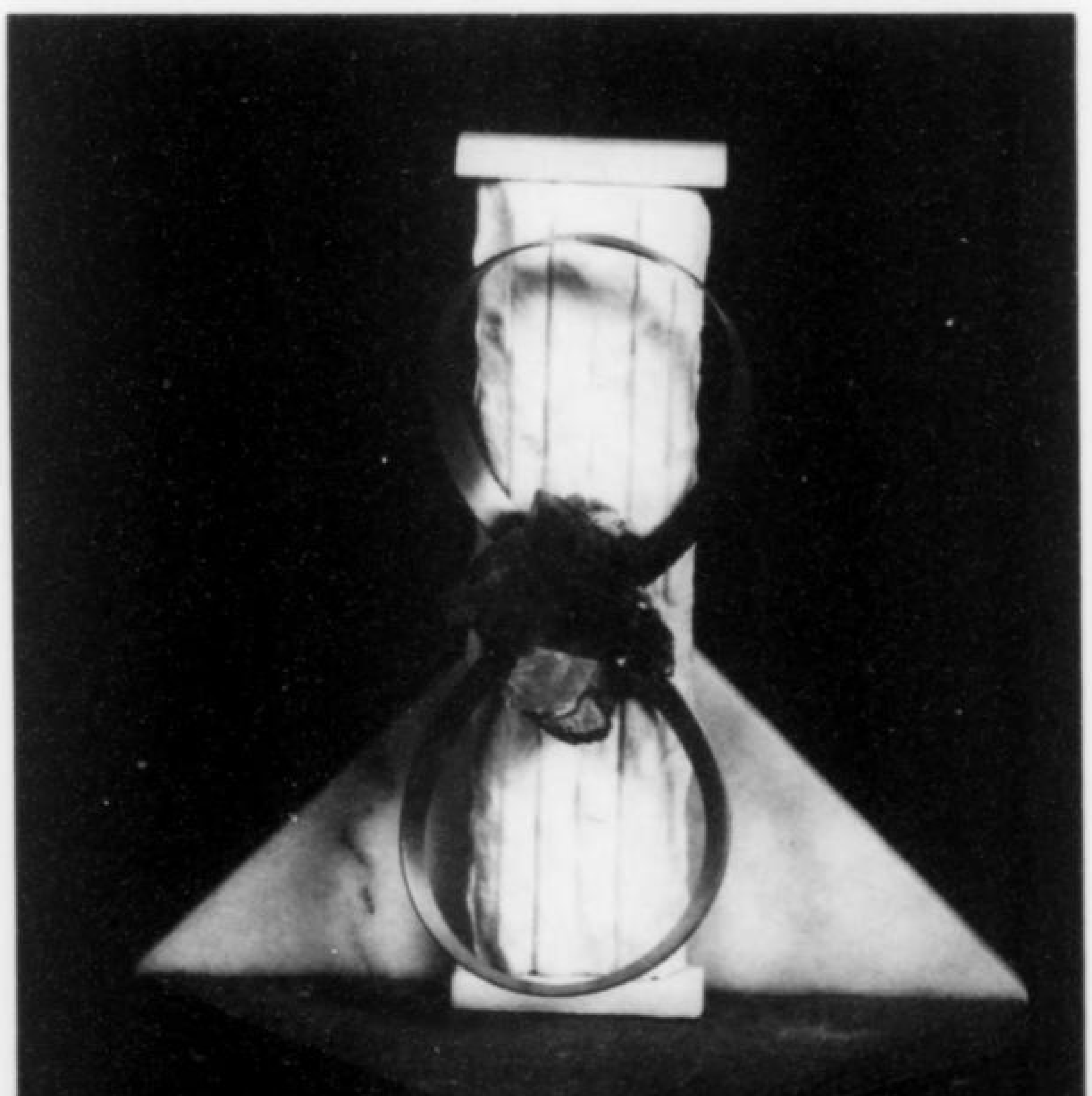


Figure 144. **Colorado Governor Romer presented one of these gifts to each of the heads of state during the *Summit of the Eight* conference held in Denver. Each gift features materials found in Colorado. The rhodochrosite is from the Good Luck Pocket. Photo by John Haertling.**

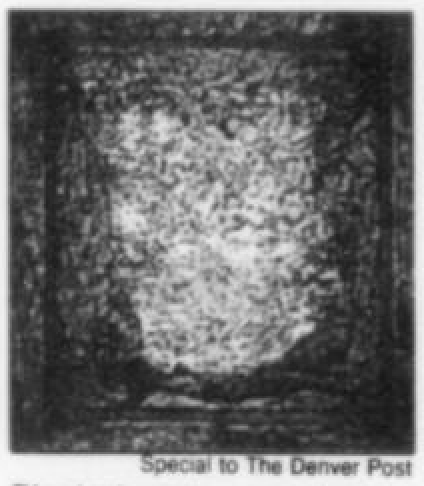
Monday, December 8, 1997 THE DENVER POST

'Vug' moves from mine to museum

By Ann Schrader
Denver Post Medical/Science Writer

A wall of brilliant red, purple and black crystals on a sparkling background of white crystals stuns visitors who wander into one of the Denver Museum of Natural History's newest exhibits.

The reconstructed mine pocket took more than two years to design and reassemble in the museum's Coors Mineral Hall. The pocket, called a vug by miners, was found in the same high-altitude Colorado mine as the famed Alma King rhodochrosite crystal.



Special to The Denver Post

Rhodochrosite crystals from Alma's Sweet Home Mine.

The 7-foot-by-8-foot wall is sprinkled with hundreds of deep-red, translucent rhodochrosites, with the liberal accompaniment of black sphalerites, purple fluorites, shiny tetrahedrites and gold-like pyrites.

Over the years, the Sweet Home Mine, located near the Park County town of Alma, has produced many unusually well-formed crystals of various minerals. The old silver mine had yielded many museum specimens of rhodochrosites since it was reopened in 1991 by geologist Brian Lees.

Lees found the Alma King — a 6-inch-long, 5-pound pristine squashed square of rhodochrosite —

Dazzling crystal wall moves from mine to new museum exhibit

CRYSTALS from Page 1B

at the Sweet Home. Then in September 1994, as snow began to fall in the 10,000-foot-high area of the Mosquito Mountains, Lees found the crystal wall.

Both the wall and the world-class Alma King now have homes at the Denver Natural History Museum where they are displayed, thanks to funding by the Adolph Coors Foundation.

Jack Murphy, the curator of geology, wrote in a museum publication that the idea to recreate the mine's setting "offers much more in educational value than if it were displayed as an isolated specimen."

The reconstructed vug reveals one environment where minerals form. In the case of the Sweet Home Mine pocket, the story of its creation lies at the heart of how the Rocky Mountains were built.

As the North American plate moved west, oceanic plates were shoved under and the mountains began to push up in Colorado. Molten rock activity underneath drove scalding, mineral-rich waters up. As the waters pushed up, they flowed into nooks and crannies in the rock, such as the cavities found in the Sweet Home Mine.

After about 3 million years, the waters cooled, vapors condensed and minerals sprinkled out. Murphy said the minerals formed into geometric shapes known as crystals in the open spaces of veins. If there were no open spaces, the minerals formed solid veins.

The veins in the Rocky Mountains are contained in the Colorado Mineral Belt, which extends from Boulder south to the San Juan Mountains. The Sweet Home Mine is a bright spot in the belt.

To remove the crystal pocket from the mine, Lees and hard-rock miners took the wall out piece by piece. The crew used a hydraulic splitter and a diamond chain saw to remove more than a 1,000 pieces that ranged in size from 4 to 12 inches across.

In some areas, the crew used a small sledgehammer and a hand-held chisel to pry the small crystal sections from the rock.

Murphy noted that the fragile, needle-like quartz had to be removed with extreme care.

The pieces were packed and taken to Lees' business, the Collector's Edge in Golden, where they were cleaned over six months.

Then the work to reconstruct the mine began at the museum. It was decided to reproduce the crystal pocket in its natural setting complete with realistic rock work of the tunnel in which it was found.

Molds were taken of rock in the Colorado School of Mines' Edgar Mine near Idaho Springs. Exhibit designers at the museum sprayed concrete on the molds. Then the molds were mounted on wire and rebar and were painted to represent the rock surrounding the crystal pocket.

The result, Murphy said, is the "amazing crystal wall will be an exhibit to visit over and over, and to continue to learn from — that is, a real gem."

The exhibit is included in free admission for all Colorado residents on Friday.

***Figure 145.* The Coors Pocket/Crystal Wall makes its debut at the Denver Museum of Natural History in June, 1997 (finally reported in *The Denver Post* on December 8!). Article by Ann Schrader.**

continued to the southwest. This task fell to Scott. The extension proceeded 100 feet without a pocket discovery and it was decided to begin a series of raises above the 1996 finds. Rodney and Tony began developing the raise above the Hedgehog Pocket while Scott and Dean began the raise above the Mini King Pocket.

It became obvious within a month that there would be no huge discoveries made directly above the 1996 finds. The odd-year Sweet Home curse strikes again! However, a few small pockets were discovered within 50 feet above the 1996 pocket zone. These were identified with the names Rodney's Pocket, Scott's Pocket, Bill's Pocket, Robert's Pocket and Gerhard's Pocket, the last being the season's best pocket.

All of the pockets were small and contained small rhodochrosites on matrix. They made excellent miniatures. The overall quality was good despite the low production. Robert's Pocket contained the largest volume of good specimens while Gerhard's Pocket contained the best quality since the Good Luck Pocket find of 1992. Unfortunately, Gerhard's Pocket only produced four nice specimens.

By mid-season, Rodney and Tony stopped working in the raises and were put in charge of driving a new exploratory drift to the northeast of the old Main Stope. This new drift became the Main Stope Extension Northeast. This was uncharted ground. After the

***Figure 146.* Fluorite on quartz, 1.8 cm, Rodney's Pocket, Hedgehog Raise. Colorless fluorite is rare at the Sweet Home mine. The slight hue is caused by a small (3 mm) purple fluorite in the crystal's center. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.**

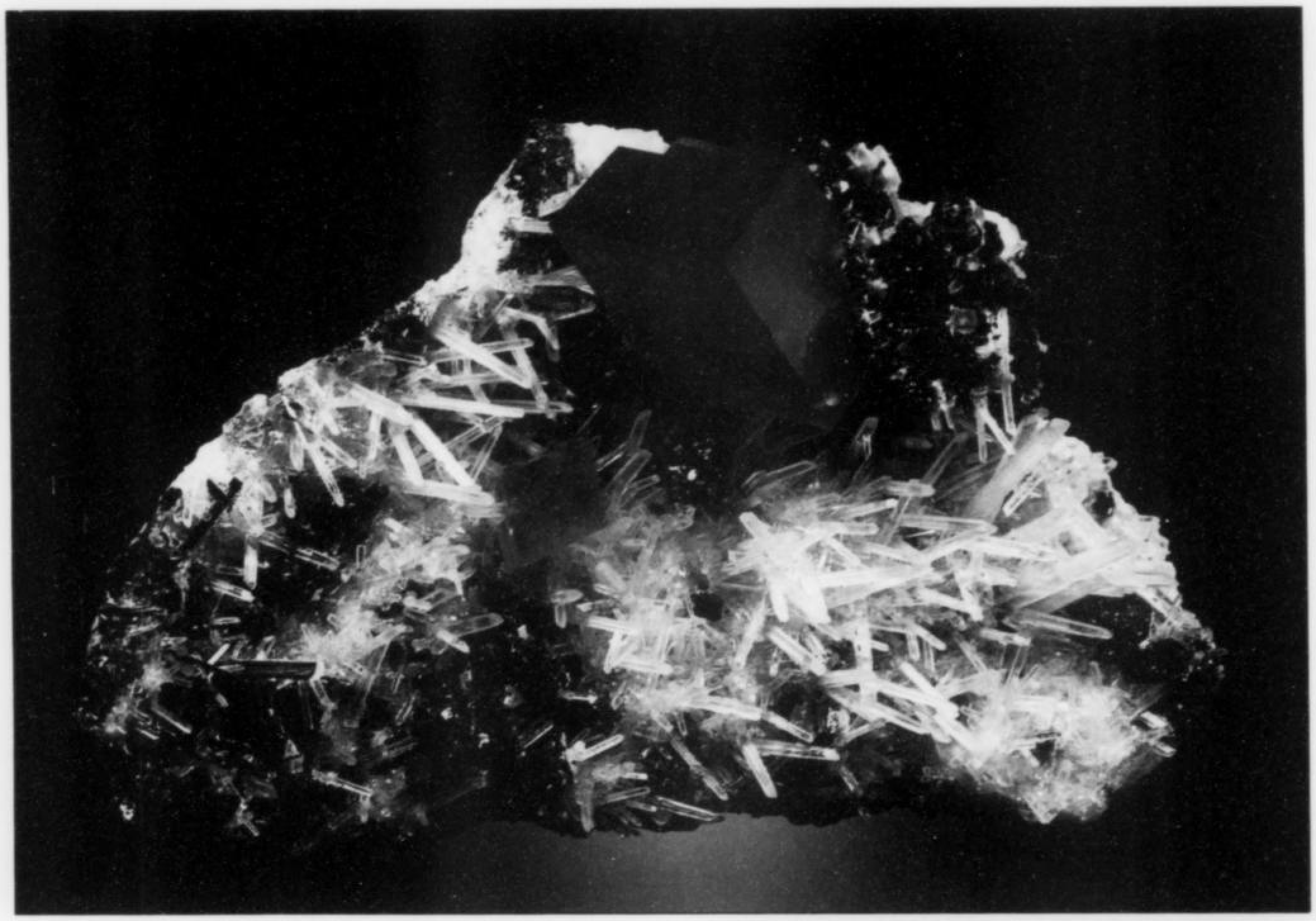


Figure 147. Rhodochrosite with pyrite on quartz, 8.8 cm, Scott's Pocket, Main Stope Extension Drift. Here, sphalerite is partially pseudomorphous after pyrite. Both sphalerite and tetrahedrite can become pseudomorphous after pyrite from the Sweet Home mine. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.

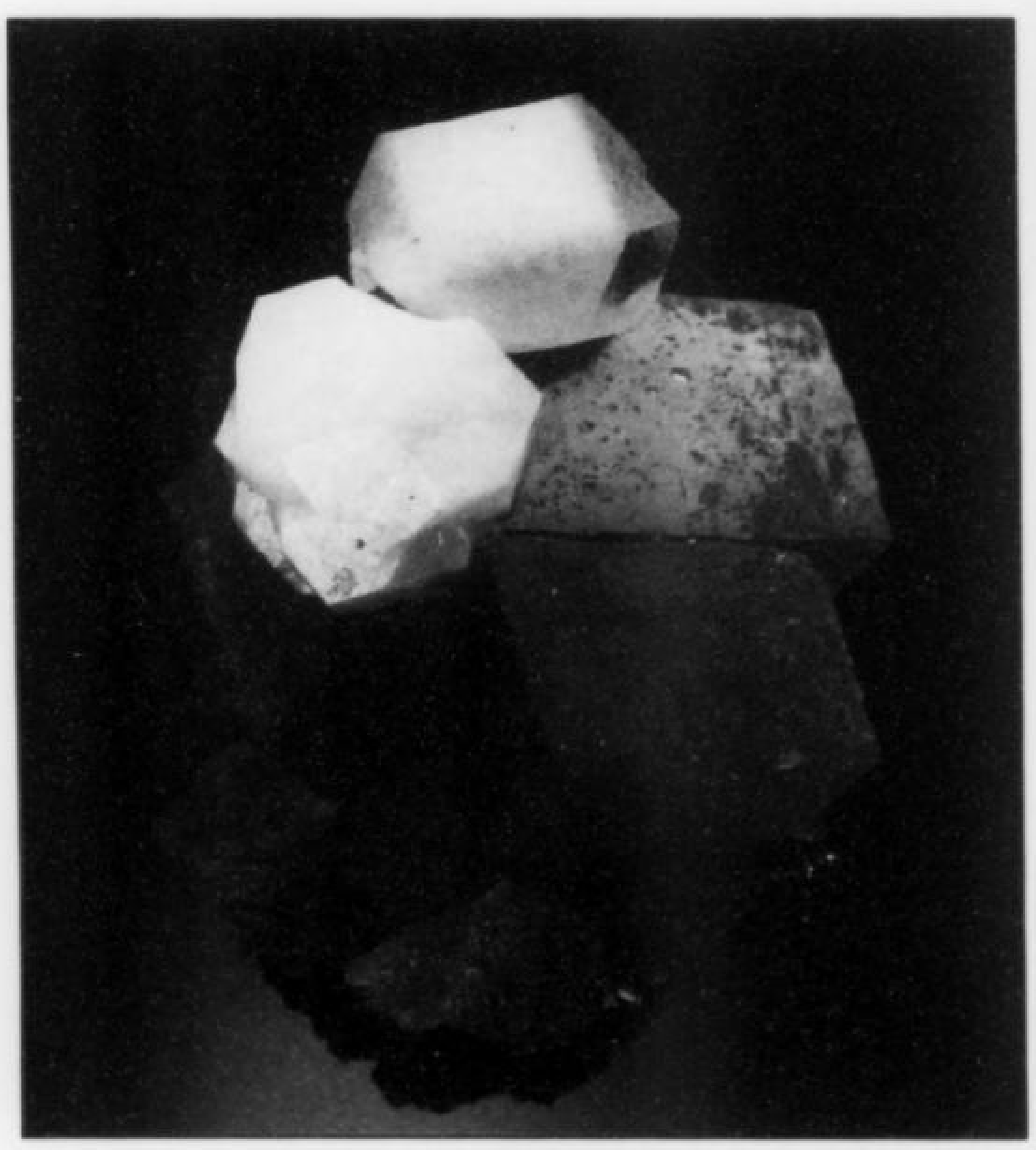


Figure 148. Fluorite on rhodochrosite, 2.9 cm, Rodney's Pocket, Hedgehog Raise. The white material making the fluorite opaque is quartz. Several pockets in the Main Stope area exhibit this type of fluorite-to-quartz pseudomorphism. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.

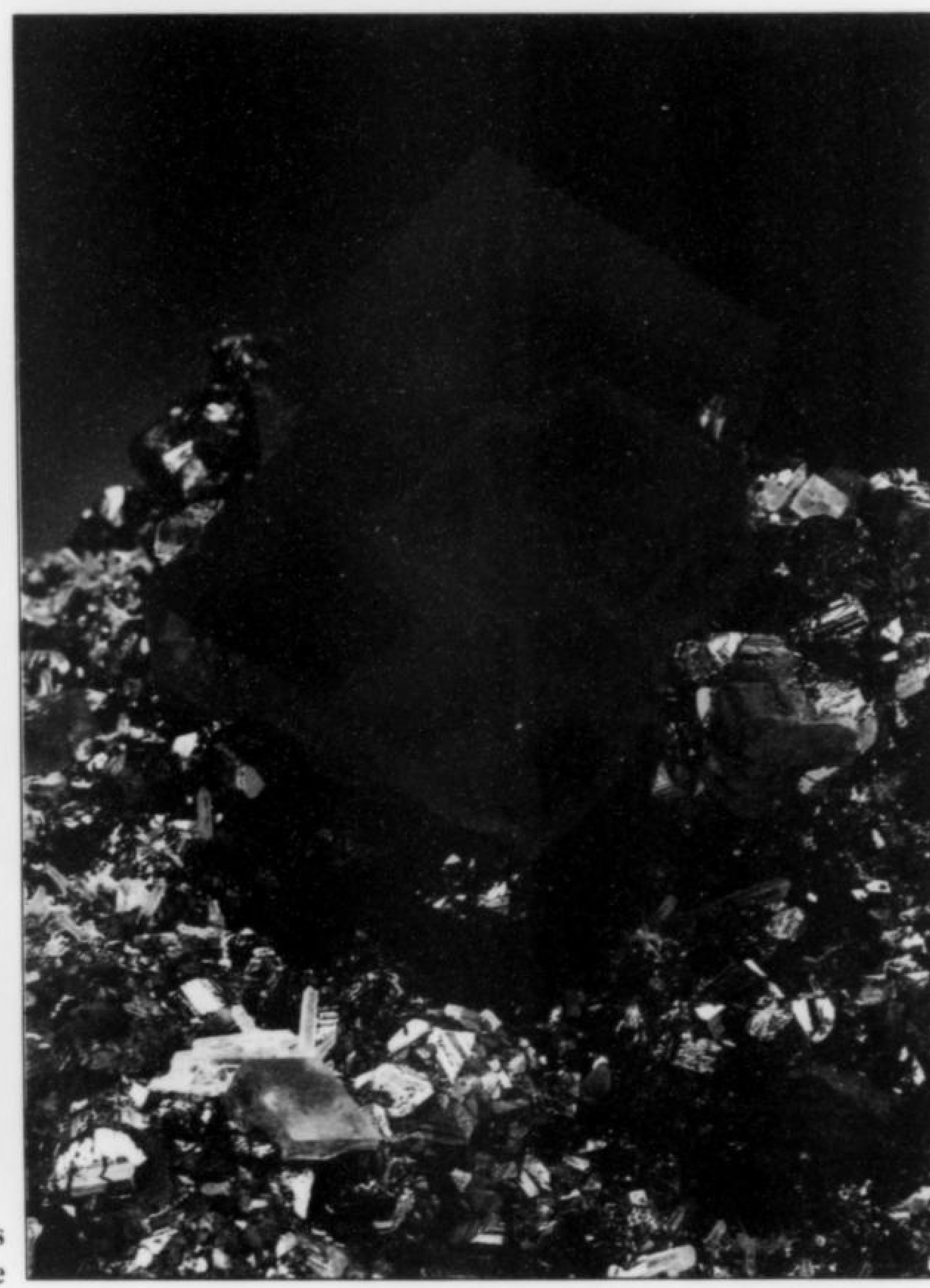


Figure 149. Rhodochrosite on sulfides, Rodney's Pocket, Hedgehog Raise; the crystal is 2.3 cm wide. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.

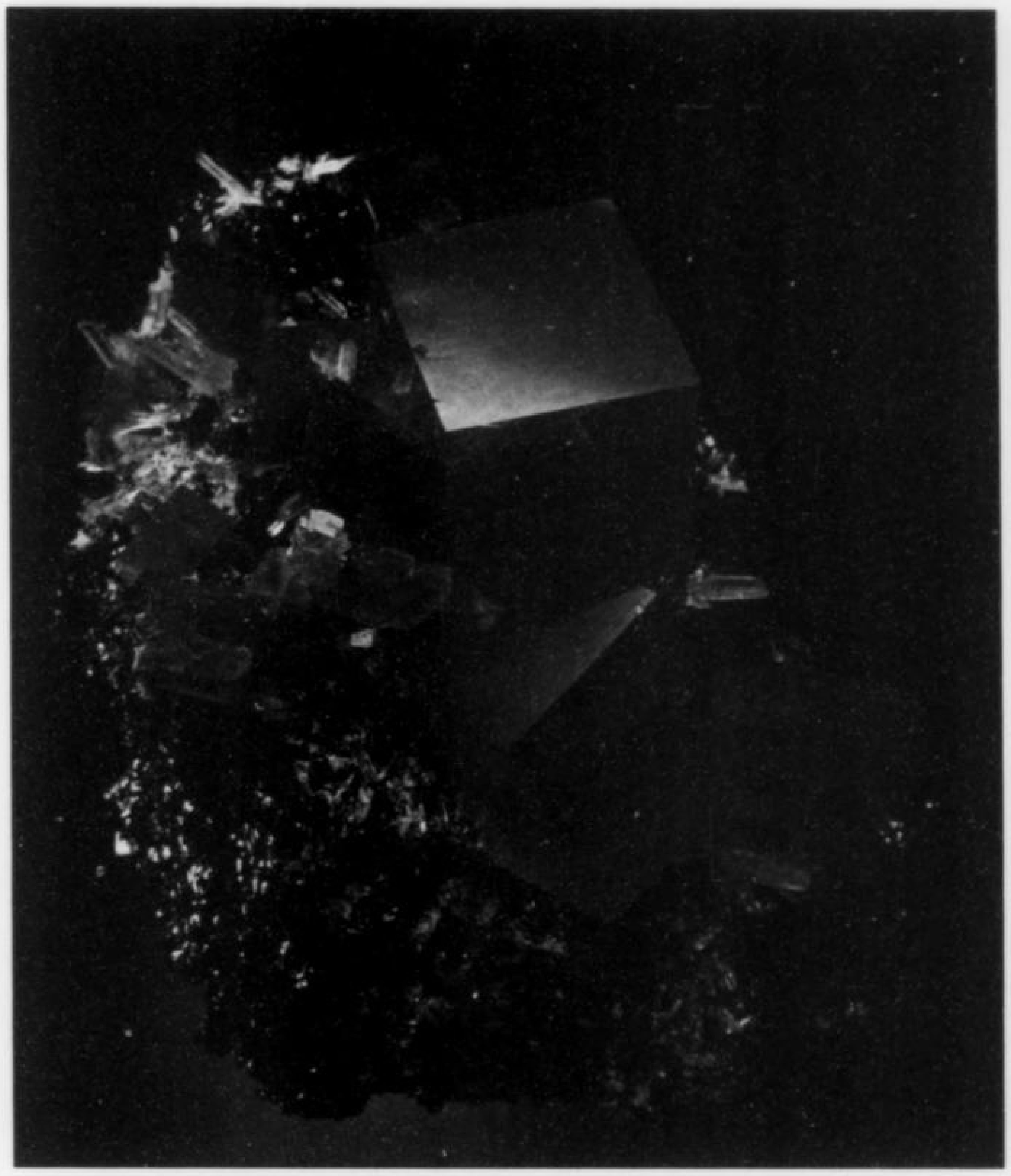


Figure 150. **Rhodochrosite, Rob's Pocket, Mini King Raise, 5.8 cm high. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.**

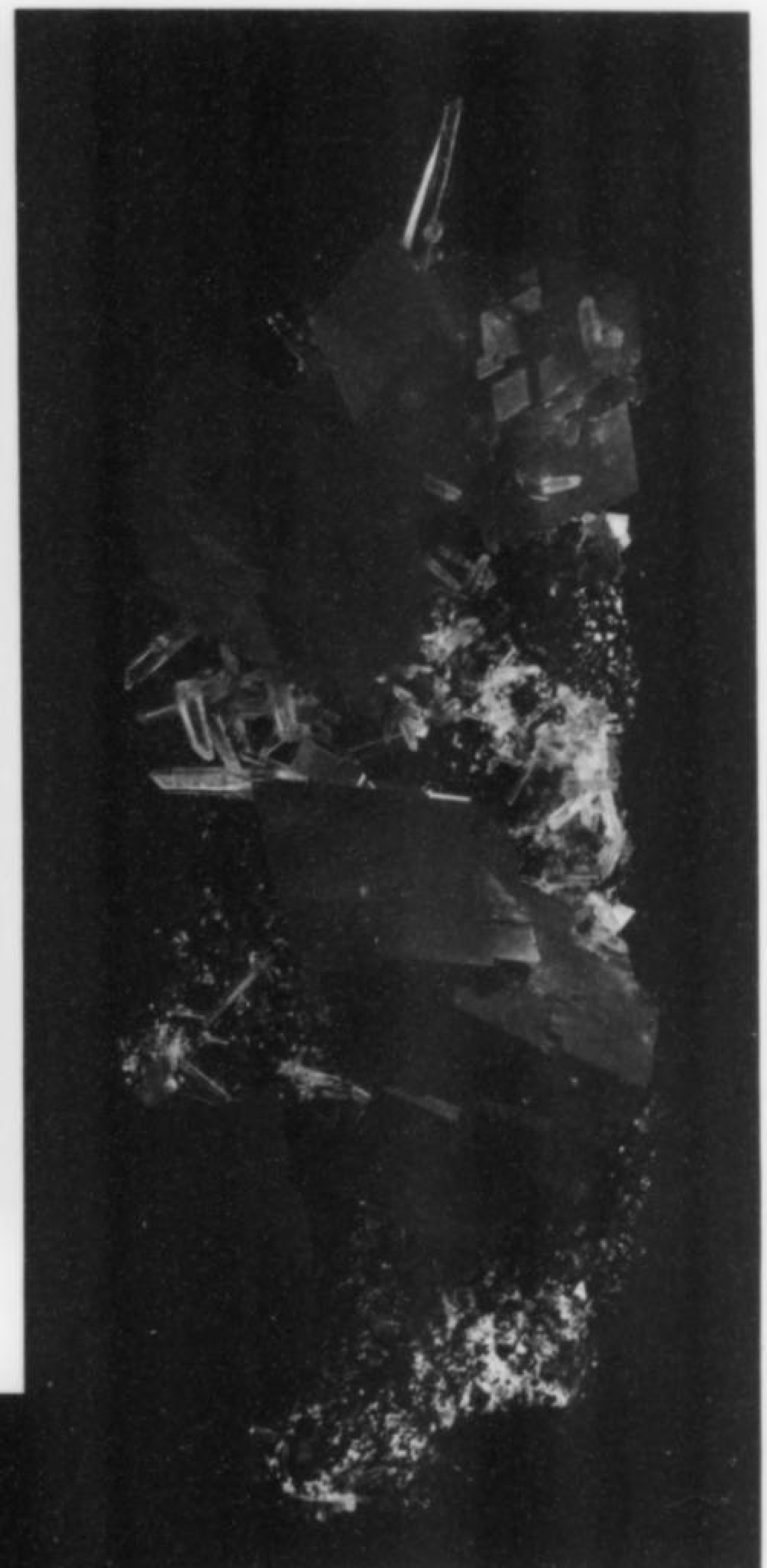


Figure 151. **Rhodochrosite with quartz, Scott's Pocket, Main Stope Extension Drift, 9.3 cm high. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.**

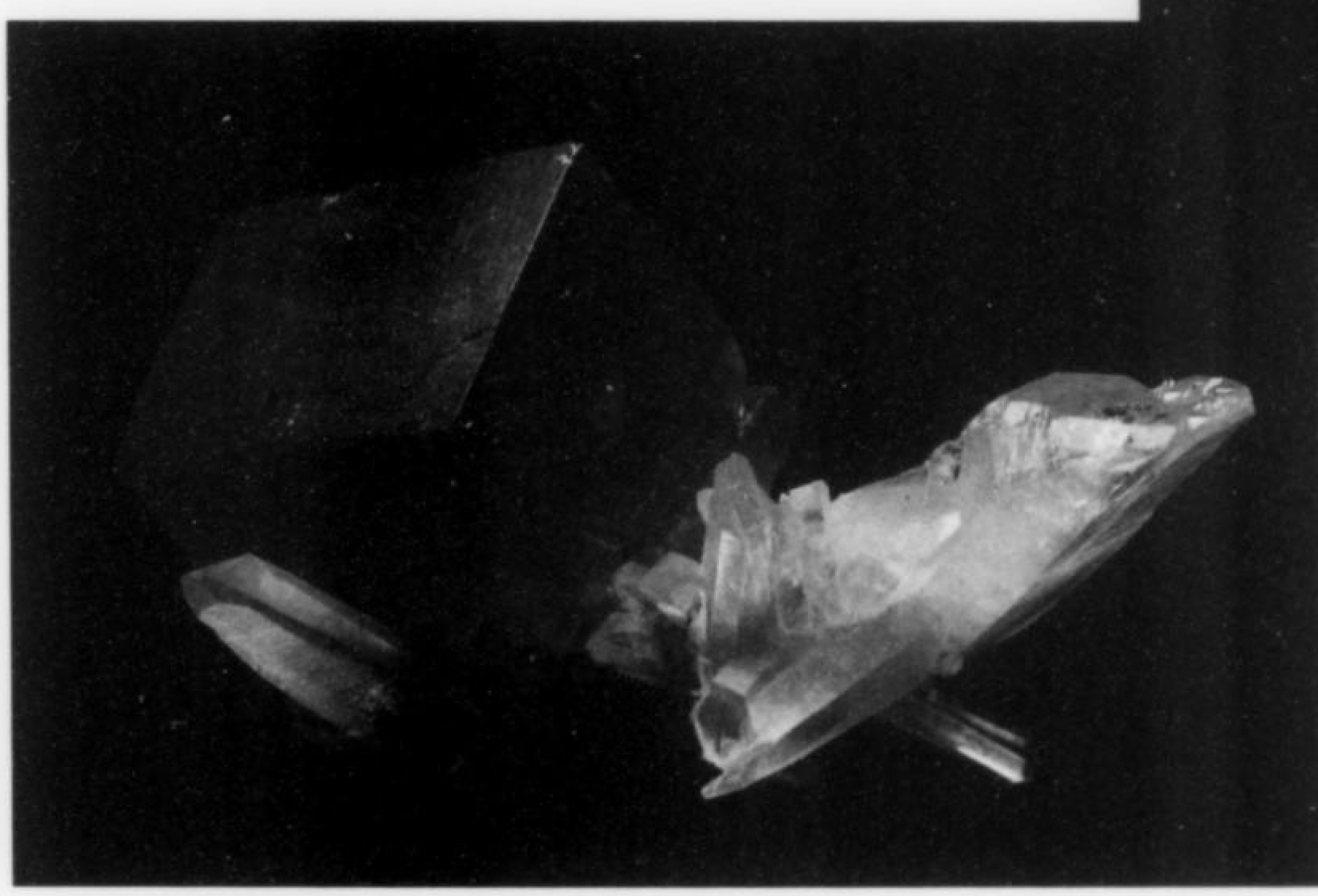


Figure 152. **Rhodochrosite on quartz, Rodney's Pocket, Hedgehog Raise, 2.8 cm wide. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.**

discovery of the pockets to the southwest of the Main Stope during the 1996 season, it was hoped that a new ore shoot would be discovered to the northeast along the same structure. This drift eventually extended 100 feet until being discontinued. Along the way, the crew intersected a rhodochrosite-bearing seam 2 inches wide and devoid of pockets. When the drift was stopped, they back-tracked and began a raise on the seam. Each 6-foot round upwards revealed open spaces for pocket development, but no rhodochrosite. By the end of November, the raise was up about 30 feet and signs of rhodochrosite were improving with the discovery of a 14-inch diameter by 2-inch wide opening containing a few 2-inch rhodochrosites. They were slightly coated and etched, but the discovery helped lift everyone's spirits.

On November 20, the air compressor had a major malfunction

Figure 153. **Rhodochrosite with hübnerite and quartz, Rob's Pocket, Mini King Raise, 9.1 cm. This is the finest example of a rhodochrosite/hübnerite combination found by the current mine operators. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.**

which shut the mine down for the season. The equipment was pulled out and the mine was sealed shut on November 26.

The 1997 season contained all of the frustrating and difficult problems of the previous odd-year dry seasons—1991, 1993 and 1995. By season's end, the Sweet Homers were tired, beat-up and, once again, running out of cash. The old mining financial cliché of the miner, "puttin it all back in the ground," was haunting the crew and causing some rumination: "Are we going to put it all back into the ground or stop and have something left to show for our efforts?" The question is now moot, because late in 1997 the company decided to continue operations in 1998. That story is still being written as we go to press with this special issue.

Thus the Sweet Home story is, after all, still a "What's New" one: the crews will probably be putting in new blast rounds while this issue is being prepared for publication. To put it another way, what we have here is a "contemporary classic" occurrence, the term being not really at all (as sometimes claimed) an oxymoron. Wendell Wilson's recent treatise on the early history of mineral collecting reminds us that all collectors, for the last three or four centuries anyway, live and have lived while great localities relatively near to them have been producing great specimens—a fact often glibly, with easy self-pity, overlooked ("all of our good stuff is long gone"). Seldom, if ever, has one of these great localities been so well documented, so continuously, as the Sweet Home now. May this article, this whole special issue, show the extent of the debt of the collector community to Sweet Home Rhodo, Inc. for this happy reality, and may it prove how very great is the Sweet Home mine by the measure of—what else?—specimen riches past, present and to come.

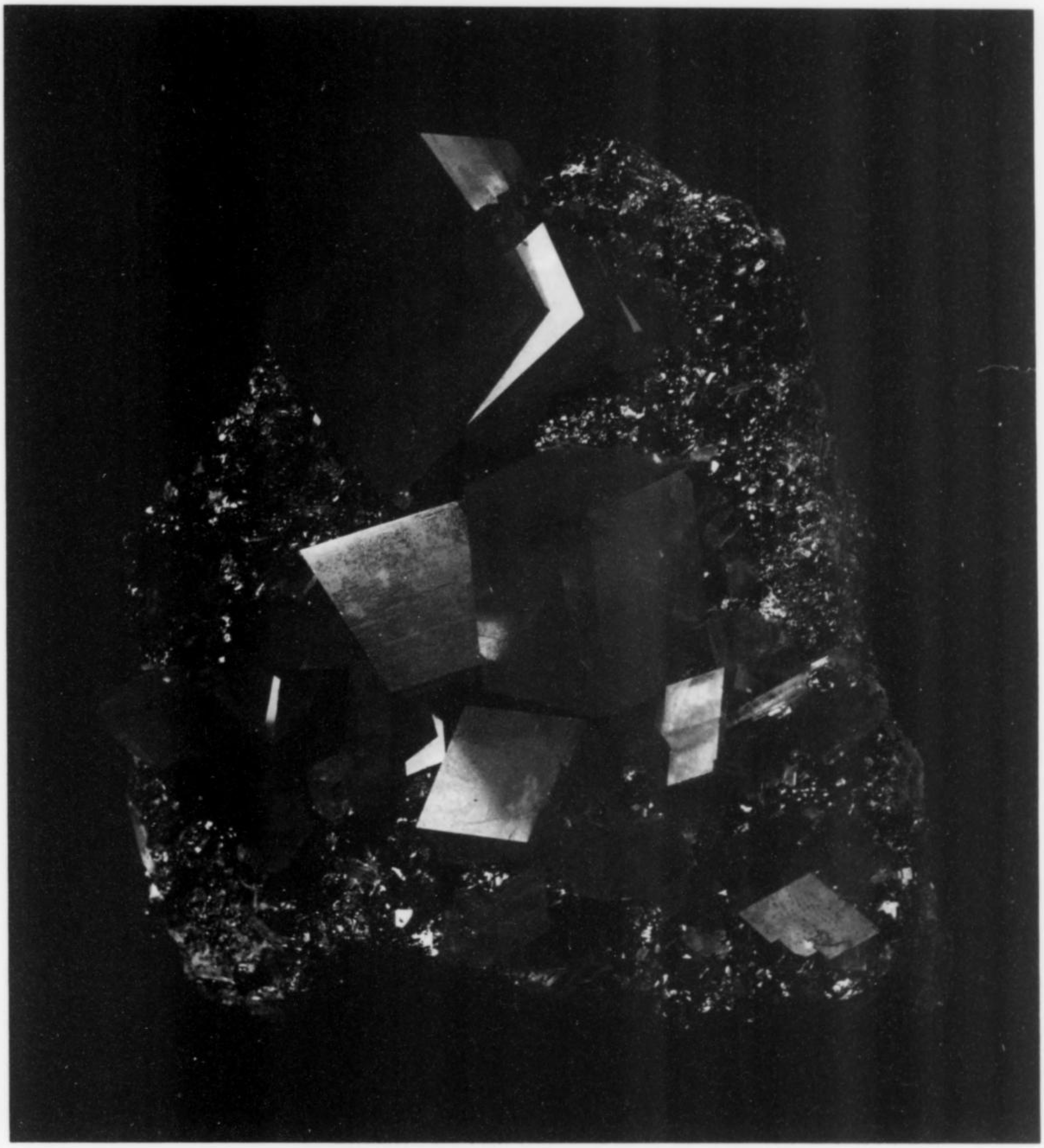


Figure 154. **Rhodochrosite on sulfides, Gerhart's Pocket, Mini King Raise, 9.5 cm. Gerhart's Pocket was the finest quality pocket of the year. Its luster and color matched that of the 1992 Good Luck Pocket. Sweet Home Rhodo, Inc. collection; Jeff Scovil photo.**

Let Bryan Lees have the very last word, a general one about underground treasure seeking:

> At the mine, 99 days out of a hundred are spent handling the daily work load. There are no pockets to explore, no crystal excitement to carry one through the rigors of the next drill station setup. Thrills are few and far between. Instead, one puts up with the constant noise and the pounding of the drills, the grueling physical work, the feeling of cold drill water trickling down your back and the ever-present grease and mud which permeate all parts of your body. Then, when you absolutely least expect it, you drill into a killer rhodochrosite

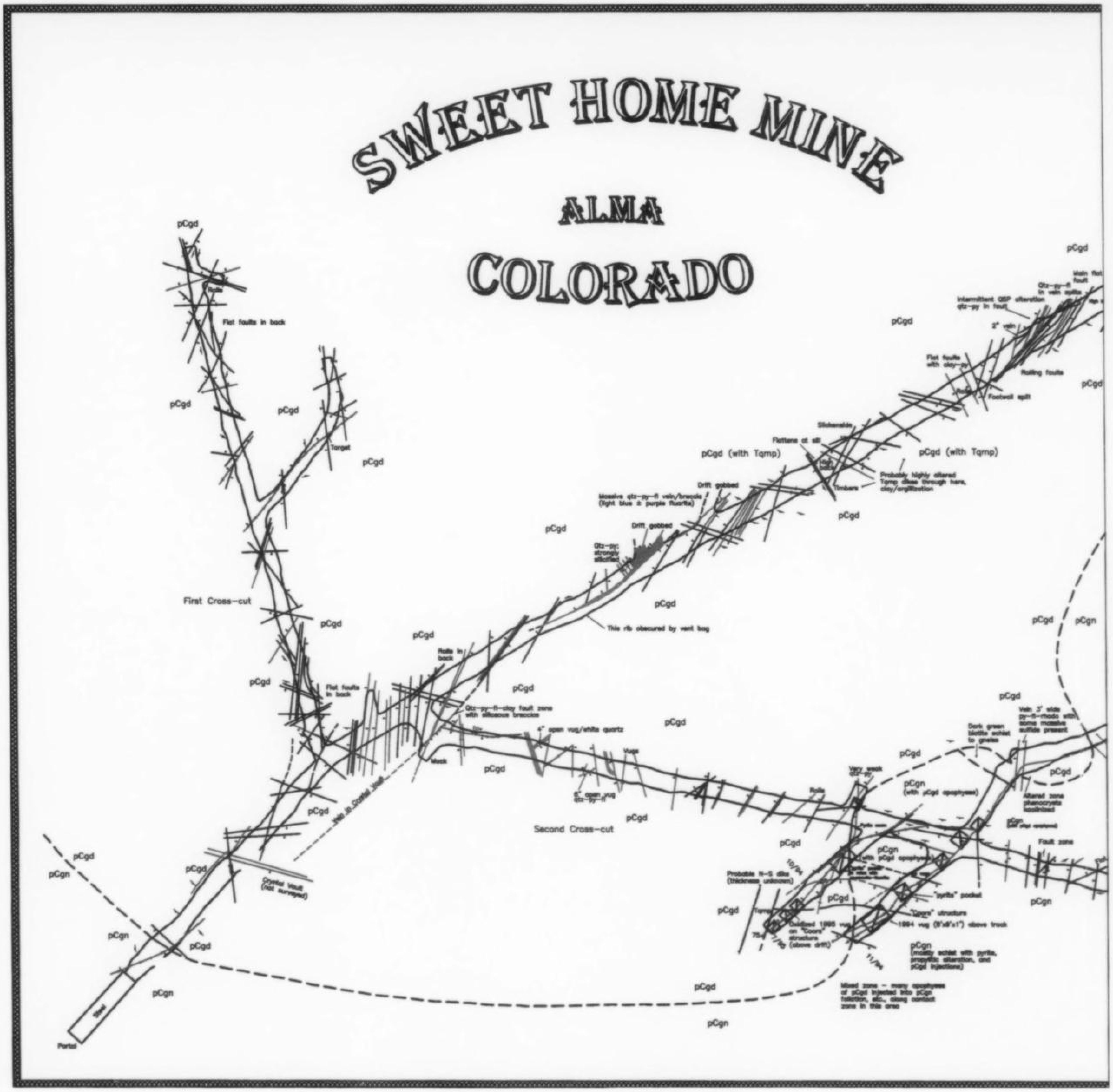


Figure 155. **Plan view of the development of the Sweet Home mine through November 1997. Graphics by Gene Kooper and Bill Tanaka.**

pocket. Suddenly, everything becomes lighter and everyone bends to the task of collecting. In seven years of mining at the Sweet Home, I've experienced this feeling at full throttle just three times. The Rainbow Pocket, Good Luck Pocket and Coors Pocket all created the intense emotional experience craved by mineral diggers and treasure hunters alike. Once hooked, one forgets the 99 days of grief and looks forward to the thrill of that one day in a hundred.

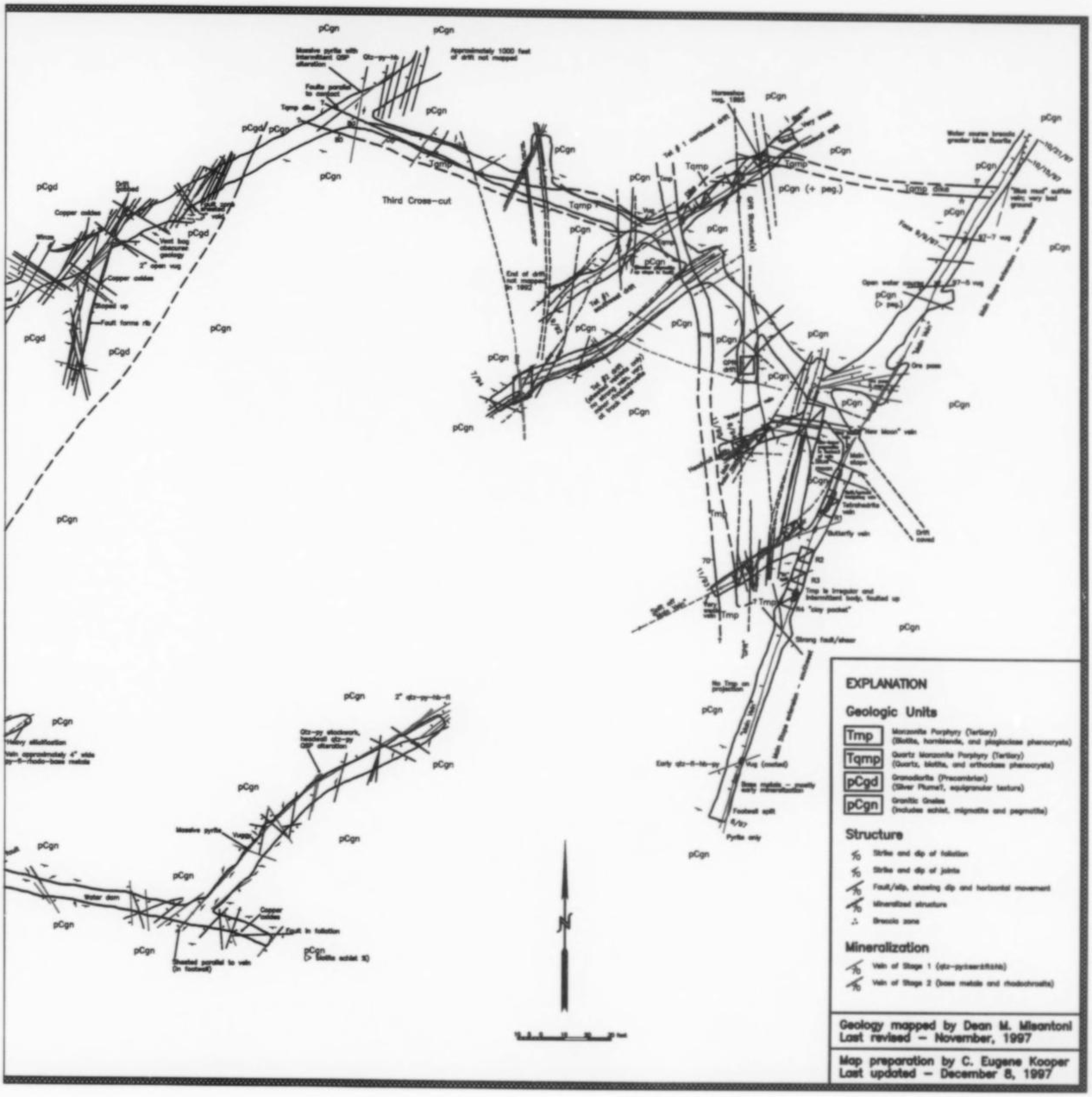

pCgn
pCgd
Tqmp
Tmp
Third Cross-cut
EXPLANATION
Geologic Units
Tmp
Monzonite Porphyry (Tertiary)
(Biotite, hornblende, and plagioclase phenocrysts)
Tqmp
Quartz Monzonite Porphyry (Tertiary)
(Quartz, biotite, and orthoclase phenocrysts)
pCgd
Granodiorite (Precambrian)
pCgn
Granitic Gneiss
Structure
Strike and dip of foliation
Strike and dip of joints
Mineralized structure
Breccia zone
Mineralization
Geology mapped by Dean M. Misantoni
Last revised – November, 1997
Map preparation by C. Eugene Kooper
Last updated – December 8, 1997

Figure 156. **Paris mill, Buckskin Gulch. The Paris mine was developed on prehistoric mine works on the cliff above the mill. The mill was built in 1894 to process gold ore from the Paris mine. Photo by Bryan Lees, 1997.**

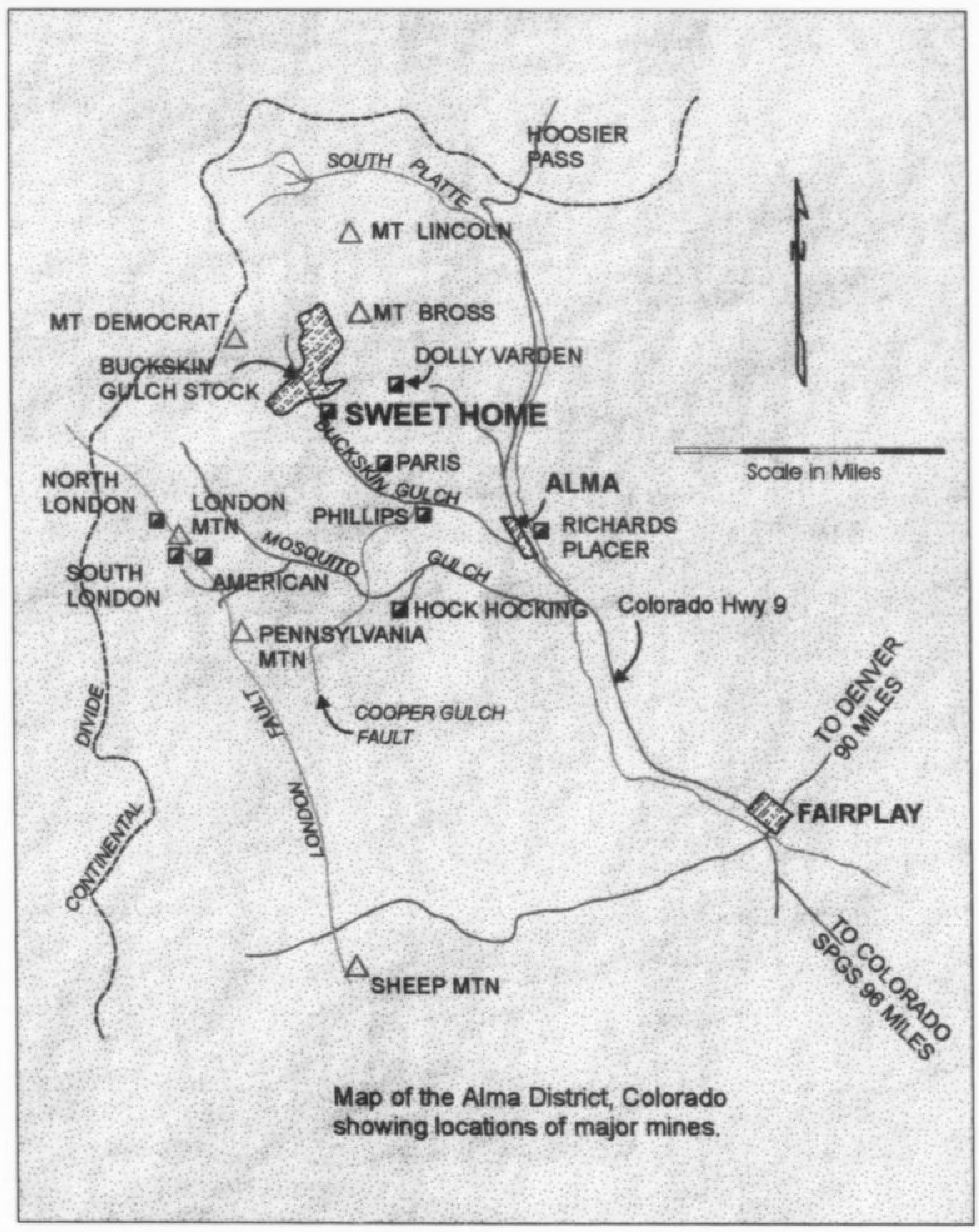


Figure 157. **Regional map of the Alma district, Colorado, showing the locations of major mines.**

GEOLOGY

GEOLOGY OF THE SWEET HOME MINE AND ALMA DISTRICT

Dean Misantoni
P.O. Box 19
Alma, Colorado 80420

Miles L. Silberman
63 S. Devinney St.
Golden, Colorado 80401

Bryan K. Lees
Sweet Home Rhodo Inc.
P.O. Box 1169
Golden, Colorado 80402

GENERAL GEOLOGY

The Alma mining district lies along the eastern slope of the northern portion of the Mosquito Range near the small town of Alma, in Central Colorado. The district has a long history of gold, silver, lead, copper and zinc production dating from pre-1850's Spanish gold prospecting to the present. A wide variety of deposit types is present, of which the Sweet Home mine type is perhaps the most mineralogically unusual occurrence. Recent mining activity (1980's until present) has centered on (1) gold production from veins at the gold-rich London sub-district, (2) Placer gold production from glacial, colluvial and alluvial gravels, and (3) rhodochrosite and associated mineral specimen mining from the Ag-base metal veins of the Sweet Home mine area.

The Mosquito Range is a north-south-trending range consisting of gently east-dipping Cambrian through Pennsylvanian sedimentary rocks. This package of sedimentary rocks overlies Precambrian igneous and metamorphic rocks and represents the eastern limb of the Sawatch Anticline, which dips into the South Park Basin. The region has been intruded by a variety of Laramide to Tertiary igneous stocks, dikes, and sills (Fig. 160). Thrust faults, reverse faults and normal faults have (1) offset the east-dipping sedimentary rocks and underlying Precambrian rocks, (2) locally controlled the emplacement of Tertiary igneous rocks and (3) controlled the locations of the diverse mineral deposit types.

Pleistocene glaciation and downcutting of the Mosquito, Buckskin, South Platte and other drainages created the deeply incised high central Mosquito Range. Such erosion liberated gold that created placers extending into South Park, east of Fairplay. More importantly for this study, the denudation of the range exposed the underlying Precambrian and younger igneous and metamorphic rocks that host the veins of the Sweet Home mine area.

The stratigraphic section of the Alma District (Fig. 161) contains Cambrian through Pennsylvanian limestone (presently all dolomite), quartzite, and shale deposited on a nonconformable erosional surface on the Precambrian igneous and metamorphic rocks. Dioritic to quartz monzonitic intrusive rocks (possibly including some pegmatites) tend to occur as dikes and intrusive plugs in the Precambrian rocks and as sills in the overlying Paleozoic sedimentary formations.

Although the Paleozoic formations have hosted most of the precious and base-metal production of the district, the Sweet Home mine vein system is hosted by Precambrian and Tertiary intrusive rocks. A possibility exists that this vein system continues updip into the Paleozoic units capping Mount Bross above the mine and to the east (Fig. 162).

Table 2 summarizes the major deposit types of the Alma district and illustrates the uniqueness of the Sweet Home mine style of mineralization; this isolated mineral occurrence has been generally unproductive for base and precious metals, but is mineralogically unique, containing a suite of well-crystallized minerals for which it has become famous. Several lines of evidence support a theory that the Alma district could be related to the hydrothermal system that formed the Climax deposit (about 5 miles to the northwest of Sweet Home), or may be part of a separate Climax-type system. The most obvious of these features include (1) ages of 28–31 million years (Ma) determined on early vein and wallrock hydrothermal muscovite (sericite) (Silberman, 1995), similar to those at Climax (Wallace, 1995), (2) the presence of pebble dikes or breccias in Buckskin Gulch, (3) scattered quartz-orthoclase pegmatite bodies (containing rare molybdenite) that are most likely Tertiary in age, (4) abundant amounts of fluorite, topaz and hübnerite (geochemically anomalous concentrations of Mn, Mo, F, W), (5) wall-rock alteration types including widespread quartz-sericite-pyrite, propylitic, and early

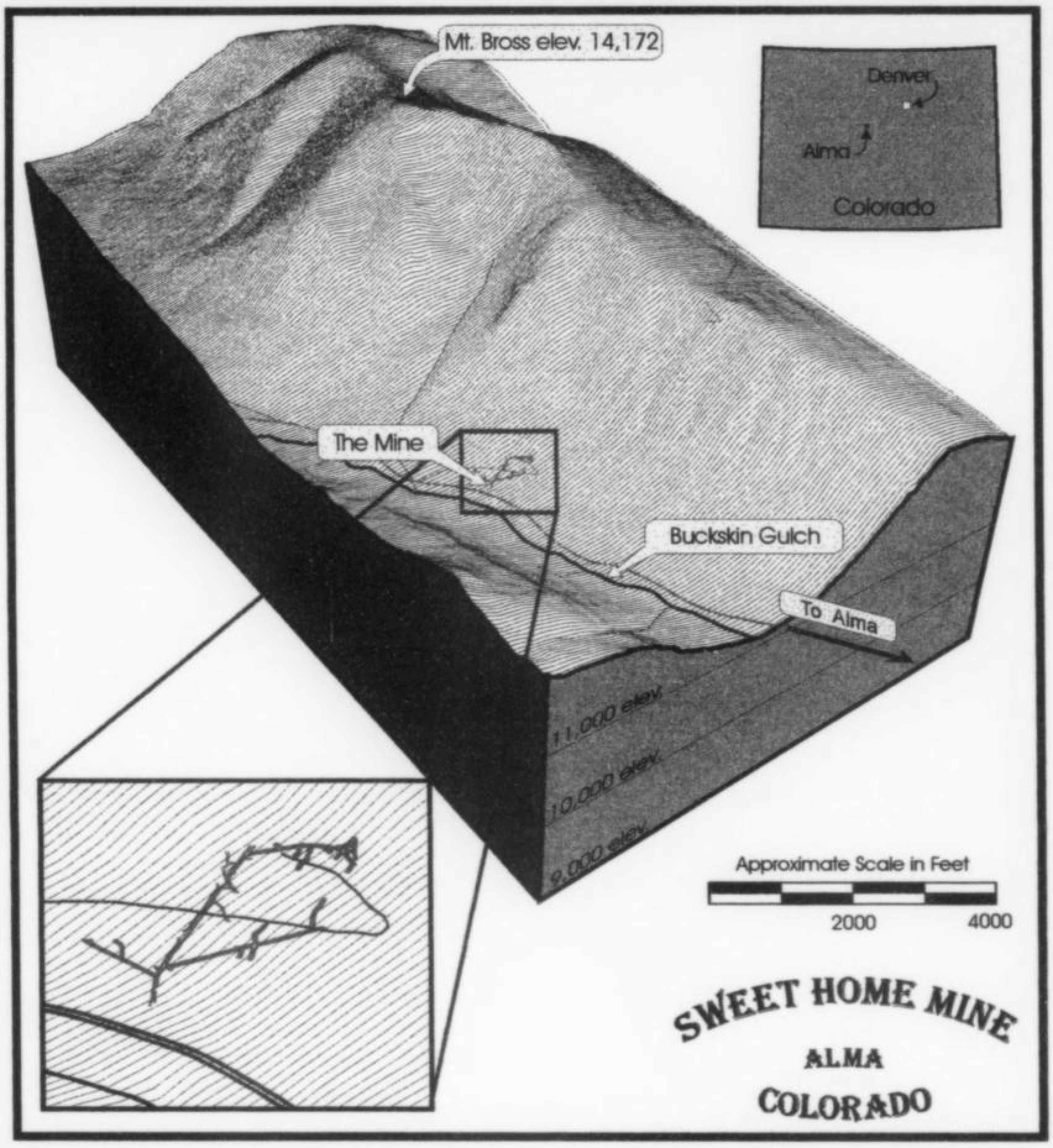
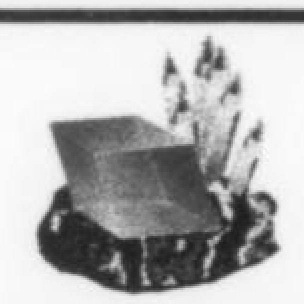


Figure 158. **Location map—perspective view of Sweet Home mine looking north-northeast.**



stage fluorite-rich hydrothermal muscovite (associated with hübnerite-pyrite-quartz veins) greisen-type alteration, (6) isolated, thin quartz-pyrite MoS_2 veins and local MoS_2 coatings on fractures in the Sweet Home mine area, particularly in association with pegmatites, (7) isotopic evidence showing a magmatic component to the mineralizing fluids, and (8) a location near Climax and along the "Climax Line" described by Wallace (1995).

LOCAL GEOLOGY

The Sweet Home mine is located at the base of Mount Bross 4 miles up from the mouth of Buckskin Gulch (at Alma) on the east side of Buckskin Creek (Fig. 164). The mine was the most productive of several properties that were developed along the northeast- and east-west-trending swarm of Pb-Zn-Cu-Ag-W-bearing veins that extend across the gulch to the southwest and northeast above the mine on Mount Bross and into the Red Amphitheater (Fig. 165). Mineralized rock extends up dip from the Sweet Home mine, to the northeast to near the nonconformable contact of Precambrian with Paleozoic rocks. Examination of the underground workings at the Tanner Boy and Queen Mary mines on the west side of Buckskin Gulch confirmed the continuity of the vein swarm to the southwest. However, correlation of individual veins from the southwest to northeast across Buckskin Gulch is tenuous.

The surface geology of the area was mapped as part of our work in an effort to locate other rhodochrosite occurrences and understand the structural controls and mineral zonation of the vein system (Fig. 164). All of the underground workings examined contain rhodochrosite. Numerous dumps and prospect pits on both sides of Buckskin Gulch also contained the Sweet Home mine rhodochrosite-base-metal assemblage. However, no other area was deemed as favorable for specimen-quality rhodochrosite as the Sweet Home, particularly when permitting and access problems were considered.

Accessible workings at the Sweet Home mine were mapped at a scale of 1 inch to 10 feet (Fig. 166). This mapping was initially designed in 1991 to locate favorable areas for mineral specimens as well as to identify unfavorable ground that could be backfilled with reasonable assurance that no crystal pockets would become inaccessible. During the on-going mapping of the workings, and over a

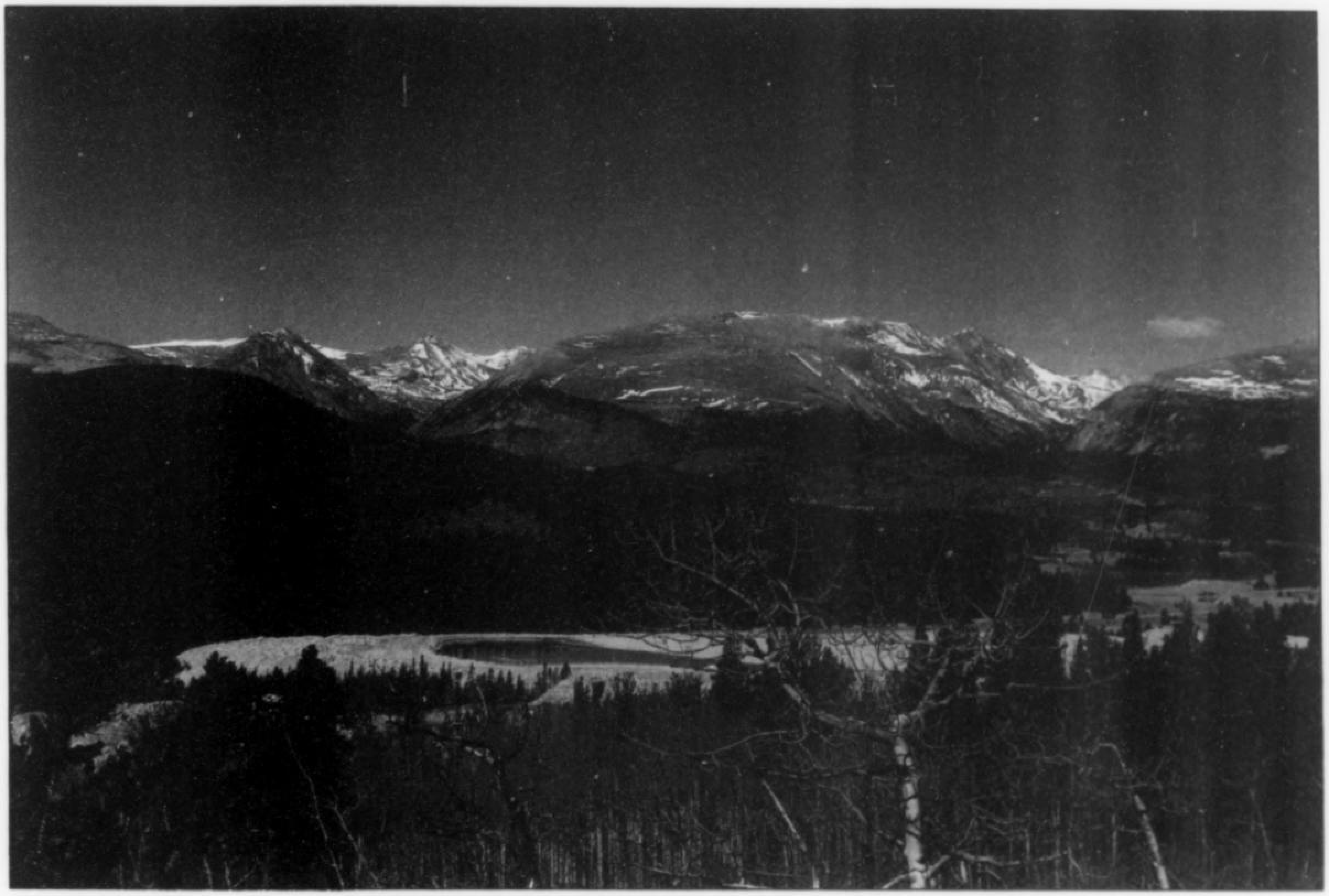


***Figure 159.* The Snow Storm Placers, Mosquito Range. The gully cutting the range on the right is Buckskin Gulch, and on the left is Mosquito Gulch. Photo by Bryan Lees, 1997.**

period of several years, much has been learned about the structural evolution and mineral paragenesis of the vein system. This mapping has greatly improved target area prediction over the past several years, focusing activity on structures with potential open space along the veins, and the later, rhodochrosite-bearing assemblage.

MINE GEOLOGY

Lithologic Units

Units exposed in the Sweet Home mine workings include Precambrian igneous and metamorphic rocks, Tertiary porphyritic intrusions, and quartz-orthoclase pegmatite bodies of possible Tertiary age (Figs. 167, 168). Paleozoic formations occur high above the mine area, and the Buckskin Gulch stock mapped further up Buckskin Gulch is not exposed in the mine workings. All units exposed in the mine are altered and were mineralized by each mineralization stage—hence, all units are premineralization. The following units are exposed in the mine:

Precambrian Granite Gneiss (P€gn)

The Precambrian granite gneiss is predominantly a banded unit containing quartz-K-feldspar-rich layers alternating with foliated biotite-rich bands. Where undisturbed, the foliation trends approximately east-west and dips moderately to the south; this is consistent with the trend observed during surface mapping in Buckskin Gulch. This rock unit contains appreciable amounts of biotite schist, migmatite, aplite, and quartz-orthoclase-muscovite-bearing pegmatite subordinate in volume to the granite gneisses. Some of this pegmatite may be Tertiary in age.

Precambrian Granodiorite (P€gd)

The Precambrian granodiorite unit occurs throughout the northwestern portion of the Sweet Home mine workings and is possibly equivalent to the Silver Plume Granite in the Colorado Front Range area. It is probably best termed a plug or small stock, and is intrusive into the Precambrian granite gneiss. In the vicinity of the intrusive contact with the metamorphic rocks there are many small tongues and apophyses of granodiorite, particularly into the foliation of the older unit. Occasionally a faint foliation defined by alignment of biotite crystals can be seen to extend from the banded gneisses into this intrusion, indicating on-going metamorphism after intrusion during the Precambrian. Some of the quartz-K-feldspar-muscovite pegmatites may be related to this intrusive mass, but others are probably Tertiary in age.

Tertiary Quartz Monzonite Porphyry (Tqmp)

The quartz monzonite porphyry occurs as dikes and irregular bodies in the Precambrian rocks. This intrusive unit is a green-gray rock containing biotite, orthoclase, and quartz phenocrysts.

Tertiary Monzonite Porphyry

This monzonite porphyry occurs in the same manner as the Tertiary quartz monzonite porphyry, but crosscuts the former and contains abundant hornblende rather than biotite phenocrysts and lesser quartz.

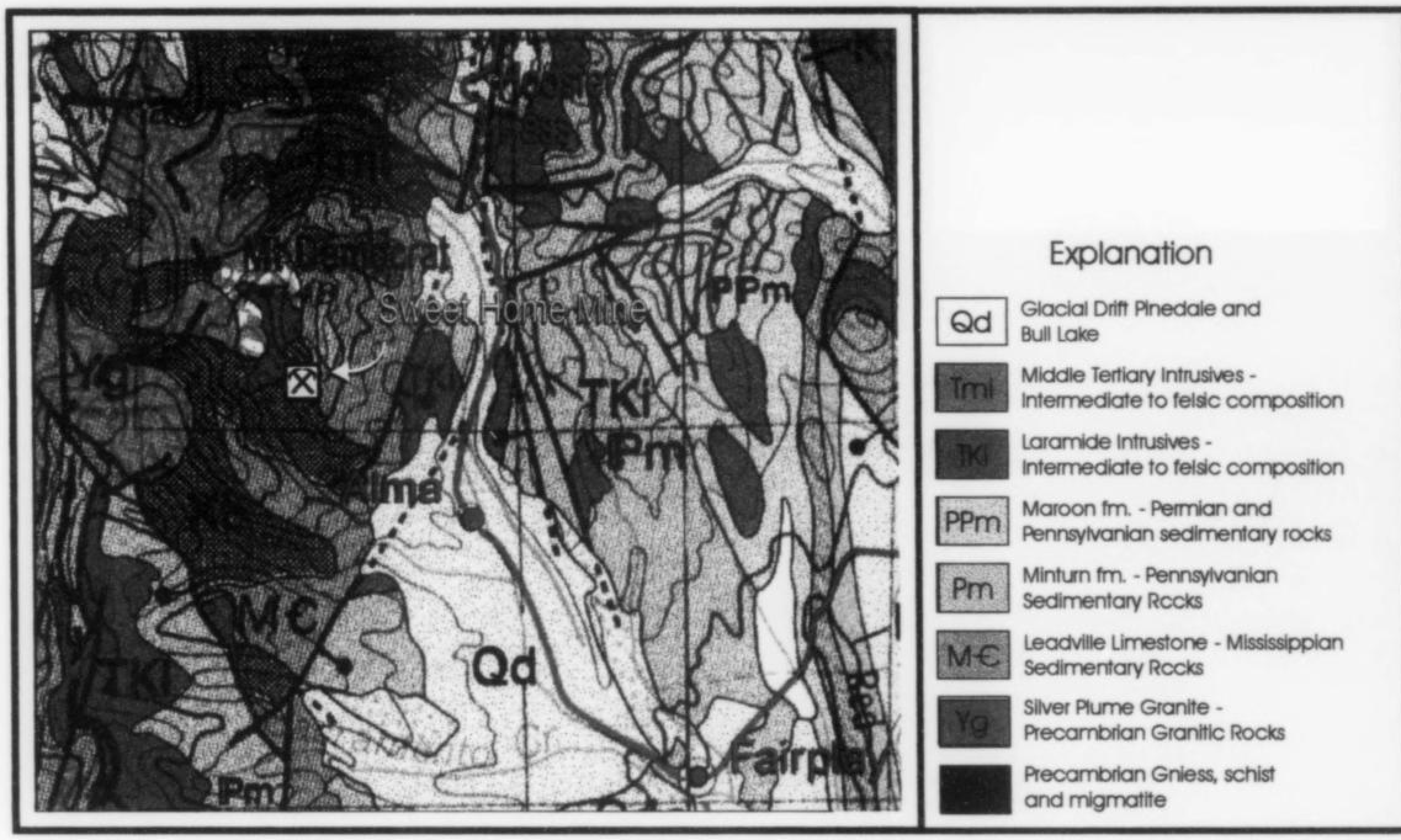


Figure 160. **Regional geologic map of the Sweet Home mine area (after Ogden Tweto, U.S.G.S. 1976 Geologic Map of Colorado).**

Stratigraphic Column

AGE	FORMATION	THICKNESS		LITHOLOGY
		Mine	Regional	
Laramide to Tertiary	Various Intrusives	5' - 15'		Monzonite to Quartz Monzonite Porphyrys
Pennsylvanian	Coffman (Belden)	> 4,000'		Interbedded quartzite, conglomerate, arkose, sandstone, shale & limestone - shale dominant at base Unconformity
Mississippian	Leadville	110'-140'	0'-160'	Dolomite, grey, coarse grained in upper part; fine to medium grained in lower part Unconformity
Devonian (Chaffee Group)	Gilman	10'-20'	0'-8'	Variable; sandstone to dolomite & fm breccias
	Dyer	60'-75'	40'-78'	Dolomite; grey to dark grey; well bedded
	Parting	5'-10'	0'-55'	Quartzite
Ordovician	Manitou	40'-50'	0'-130'	Dolomite; thin bedded to massive; white to grey; cherty
Cambrian	Peerless	65'-150'	60'-117'	Variable; quartzite in upper part; grades downward to dolomite and green to red shale
	Sawatch	58'-75'	62'-132'	Quartzite, calcareous in upper part Unconformity
Pre-Cambrian	Pre-Cambrian	Position of the Sweet Home Mine		Schist, gneiss, granite and pegmatite

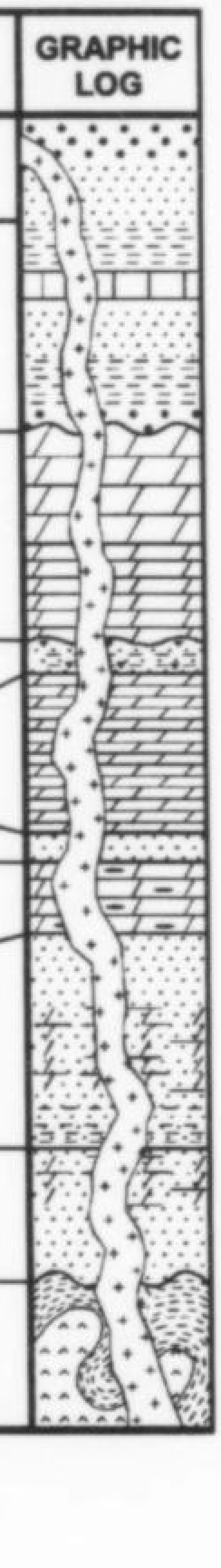


Figure 161. **Generalized stratigraphic section at the Sweet Home mine (from Singewald and Butler, 1941).**

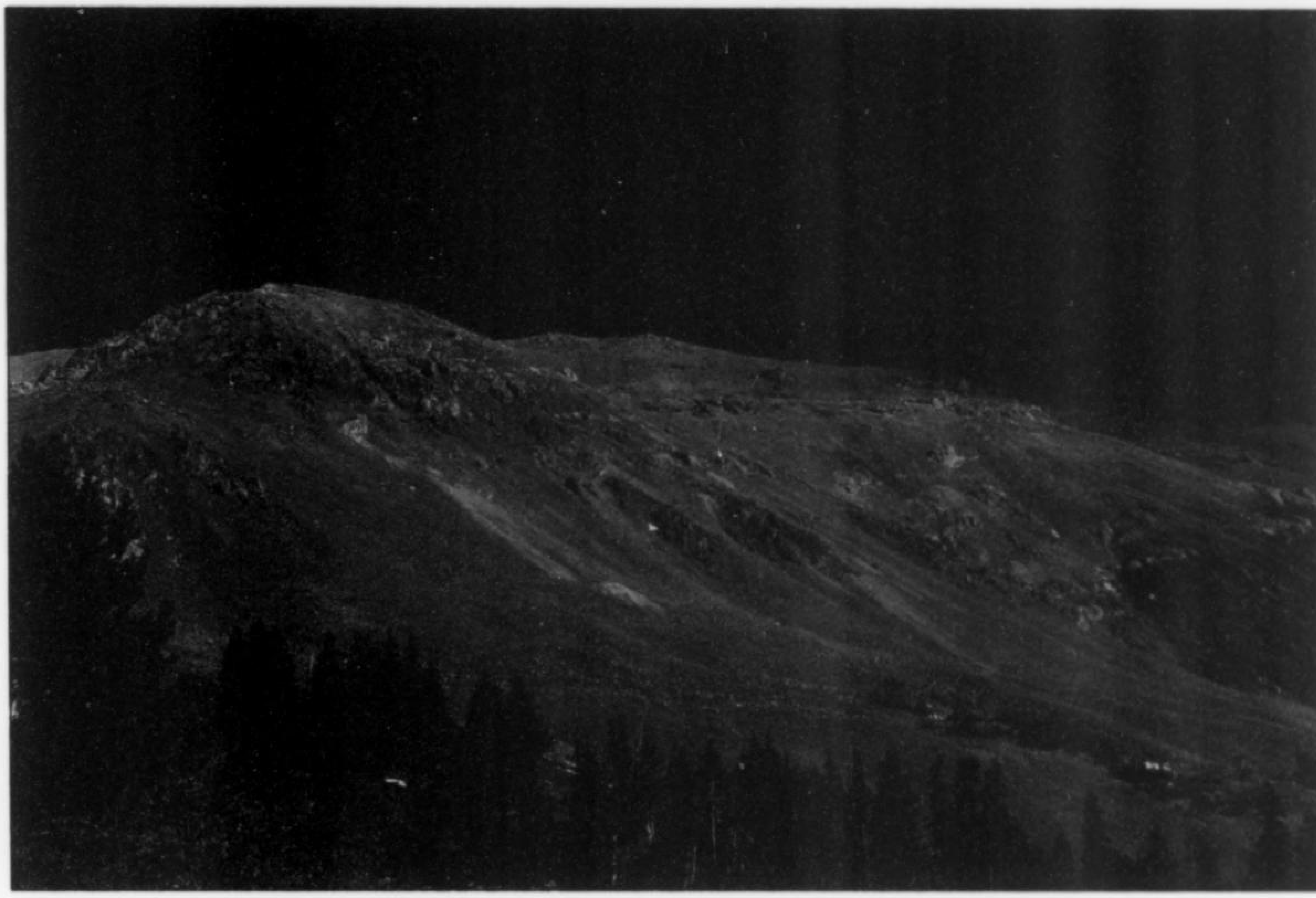


Figure 162. **Paleozoic sedimentary rocks and Tertiary sills extend across the top of Mount Bross above the mine. The rock above the mine has been extensively oxidized. The view looks down Buckskin Gulch toward the Sweet Home mine. Photo by Bryan Lees, 1997.**

Table 2. **Tertiary lode deposit types of the Alma District, Colorado.**

Deposit Type—Examples	*Metal Values*	*Host Rocks—Controls*	*Major Ore and Gangue Minerals*
1) *London Type* London American London Butte	Au (Ag, Pb, Zn, Cu)	Paleozoic sediments & Tertiary Porphyries, veins, minor carbonate replacements	Pyrite, galena, sphalerite, chalcopyrite, tetrahedrite-tennantite, dolomite, quartz, native Au
2) *Ag-Pb-Zn Replacement in Leadille Formation* Moose New York Mineral Park	Ag, Pb, Zn	Leadville Formation and lower Paleozoic Carbonates (stratiform replacements)	Galena, sphalerite, pyrite, ruby-Ag, native Ag, quartz, dolomite, barite
3) *Ag-(Au)-Pb-Zn deposits in Sawatch & Peerless Formations* Phillips Hock Hocking Orphan Boy	Ag (Au), Pb, Zn	Sawatch Quartzite & Peerless Formation, porphyry, veins, & replacements	Pyrite, galena, sphalerite, chalcopyrite, quartz, dolomite, barite
4) *Veins in Precambrian Crystalline Rocks* Champaign Sweet Home Kentucky Belle	Au, Ag (Pb, Zn, Cu) W (Sweet Home only)	Precambrian igneous, metamorphic & porphyry (narrow veins)	Sweet Home Type—quartz, pyrite, fluorite, hübnerite, molybdenite, galena, sphalerite, chalcopyrite, tetrahedrite, rhodochrosite, apatite, topaz. Other type—quartz, pyrite, galena, chalcopyrite, sphalerite, dolomite, barite, muscovite

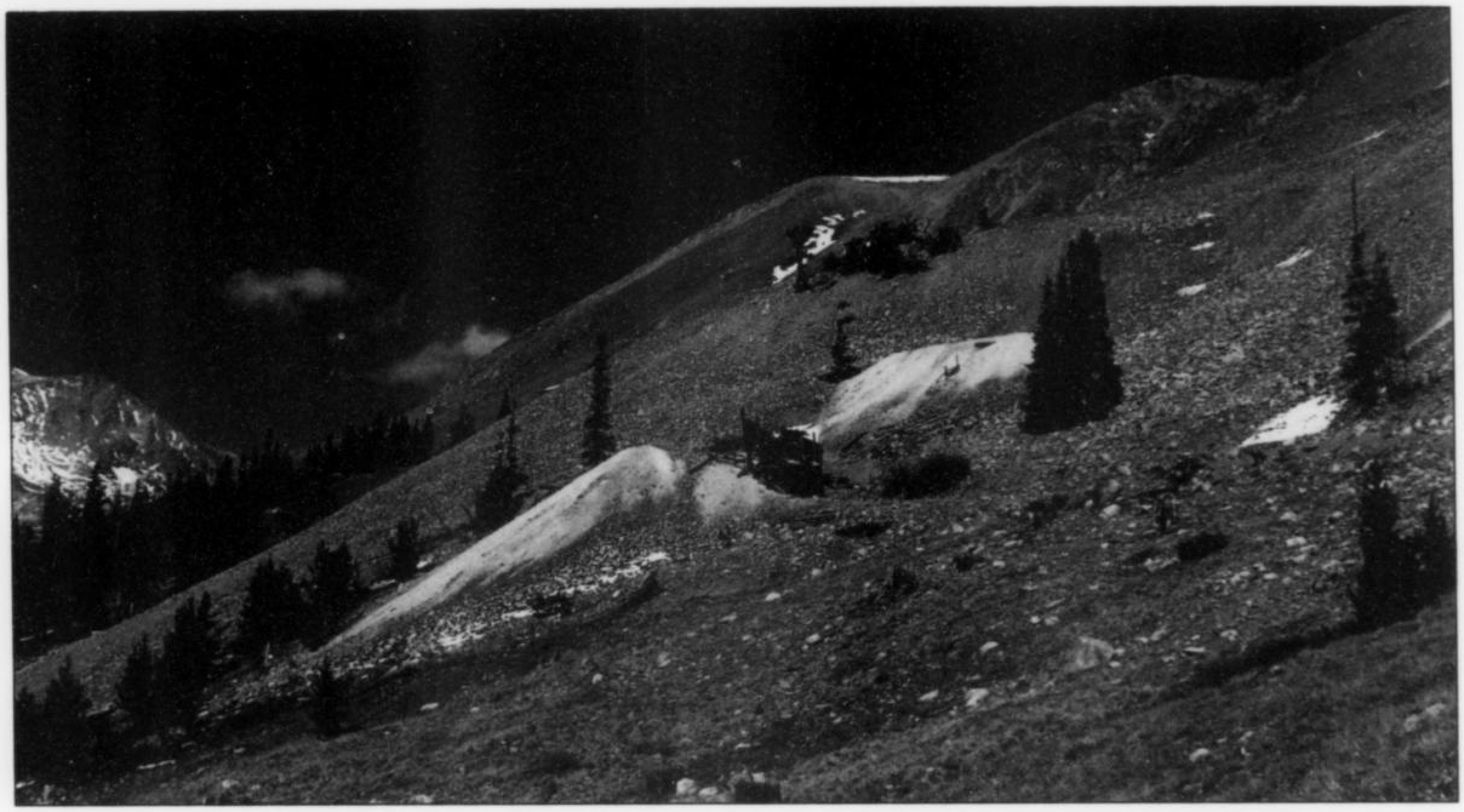


Figure 163. **Corkscrew Adit, middle workings of the Sweet Home mine. Old mine workings follow the northeast- and east-west-trending swarm of Pb-Zn-Cu-Ag-W-bearing veins that extend across the gulch to the southwest and northeast above the mine on Mount Bross. Photo by Bryan Lees, 1997.**

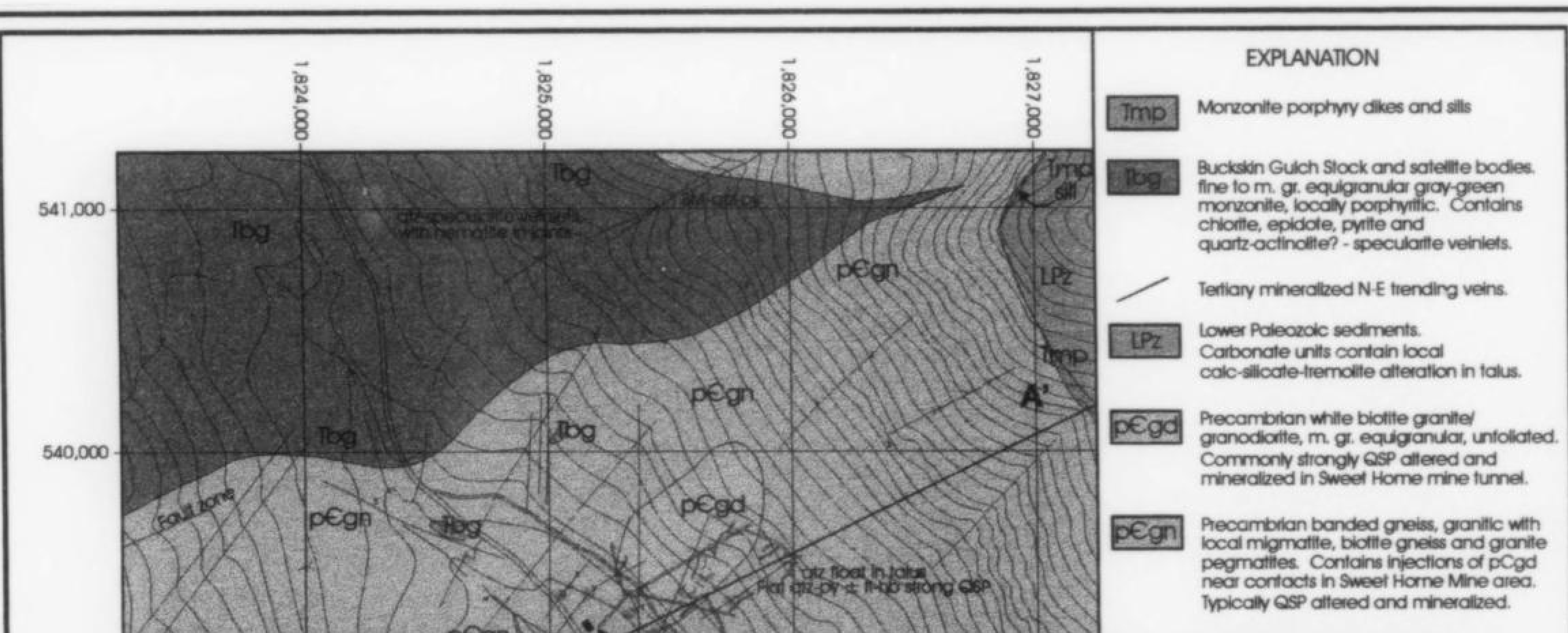


Figure 164. **Geologic map of the Sweet Home mine area.**

Figure 165. **Red Amphitheater. Photo by Bryan Lees.**

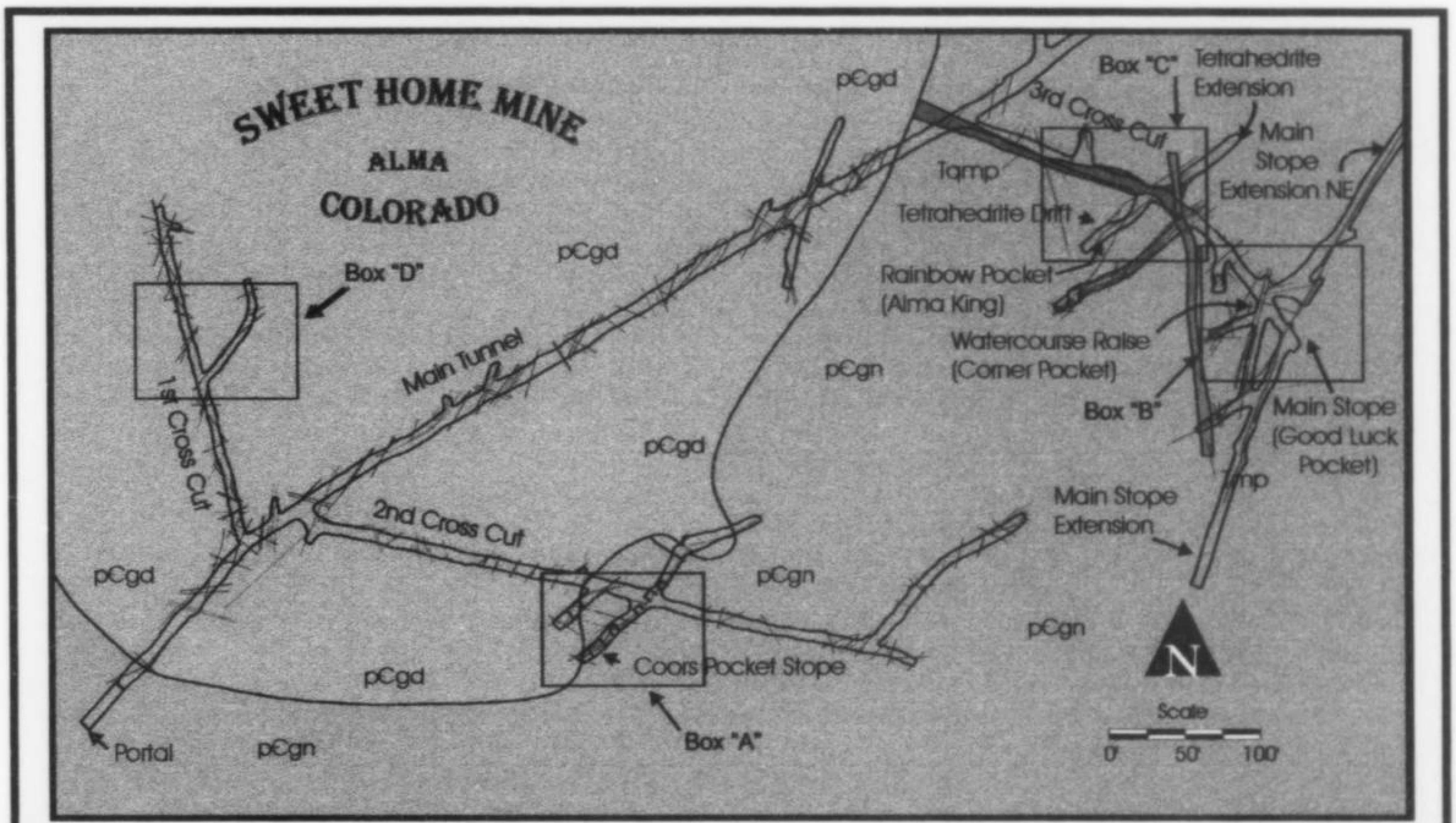


Figure 166. **Sweet Home mine geologic map showing lithology, structure and mineralization. Boxed highlights show locations of (A) Coors Stope and (B) Main Stope (see Figure 167).**

Geology mapped by Dean M. Misantoni

Map preparation by C. Eugene Kooper

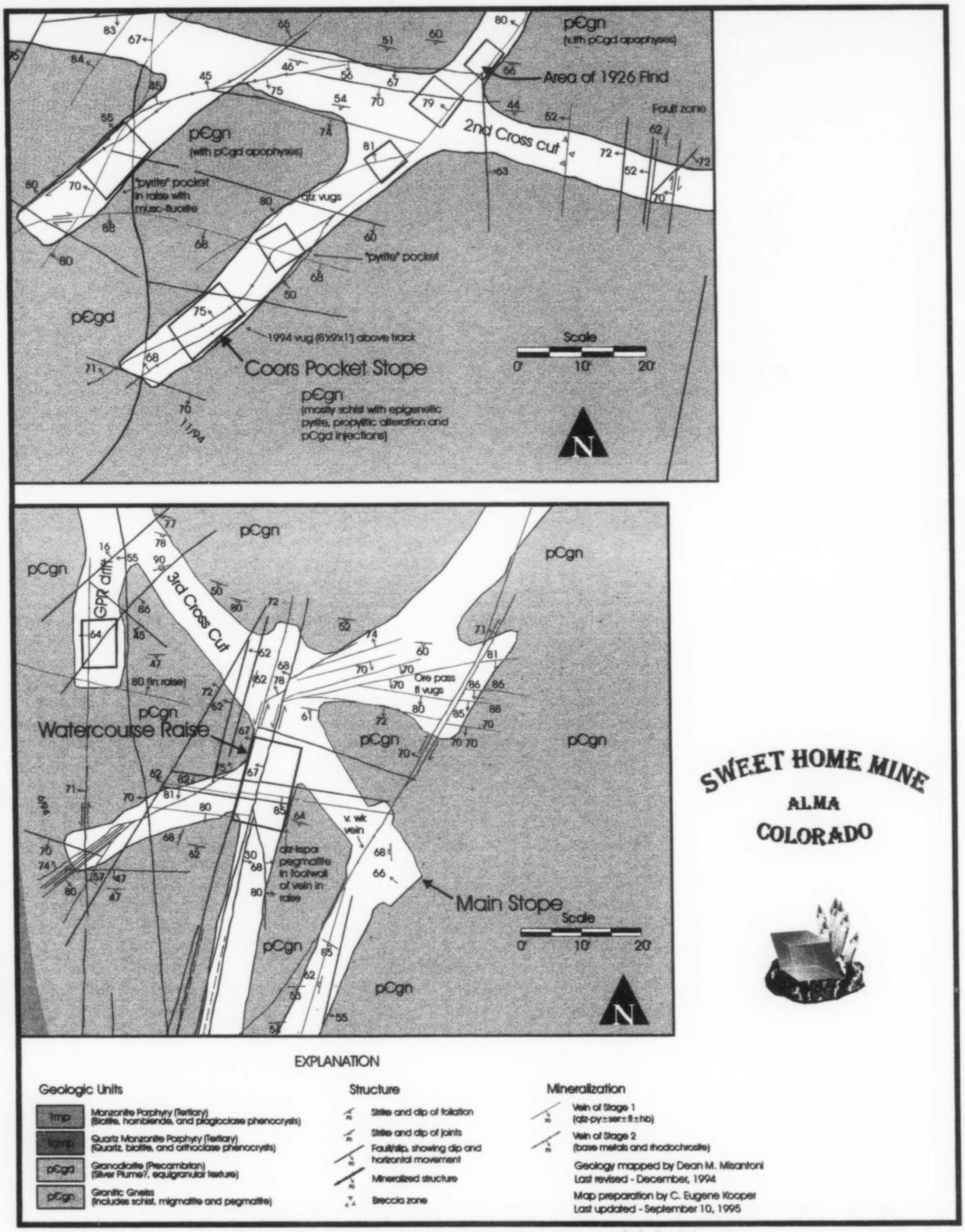


***Figure 167*. Detailed geologic map of the Coors Stope area *(above)* and the Main Stope and Watercourse Raise areas *(below)*, showing lithology, structure and mineralization.**

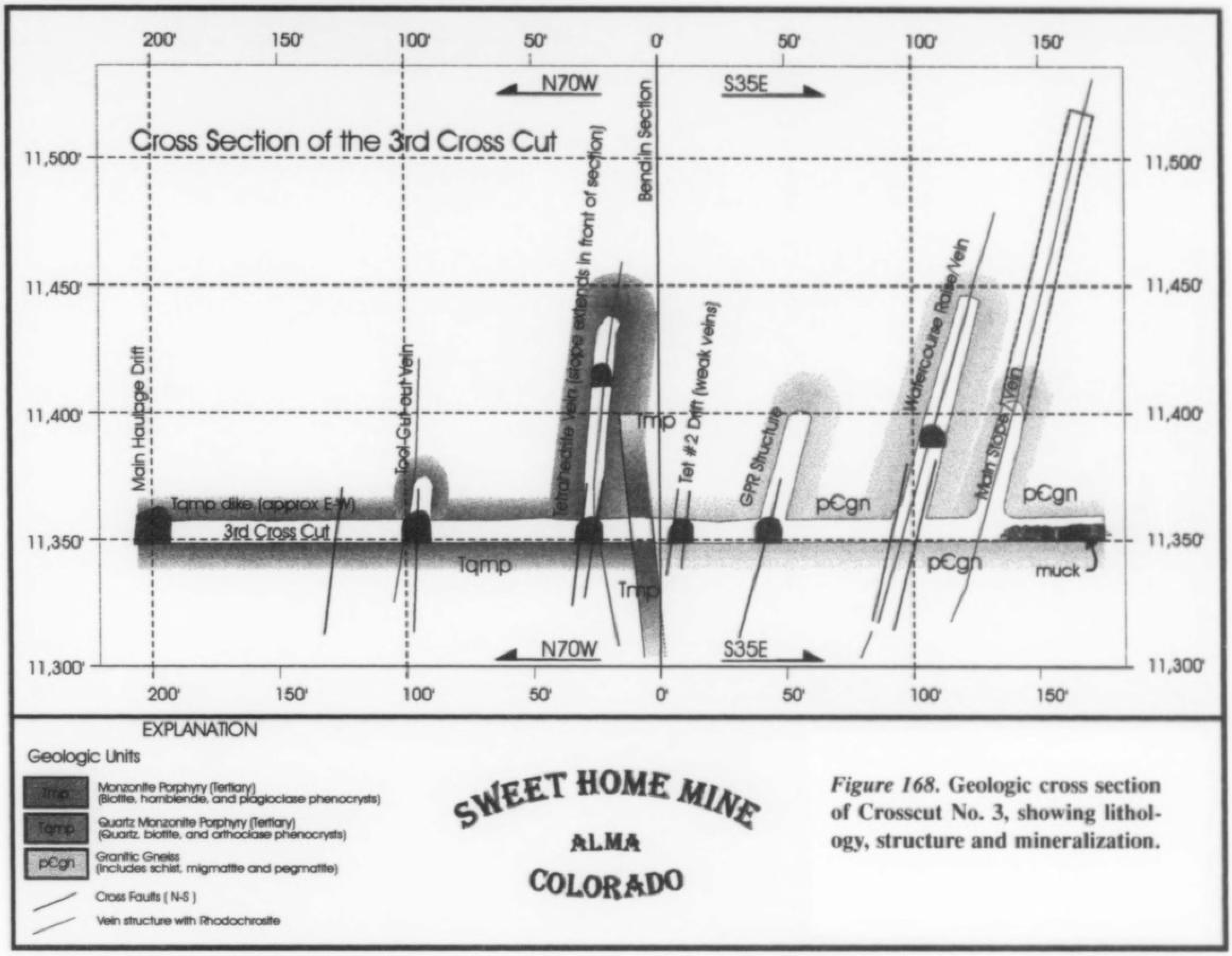


Figure 168. **Geologic cross section of Crosscut No. 3, showing lithology, structure and mineralization.**

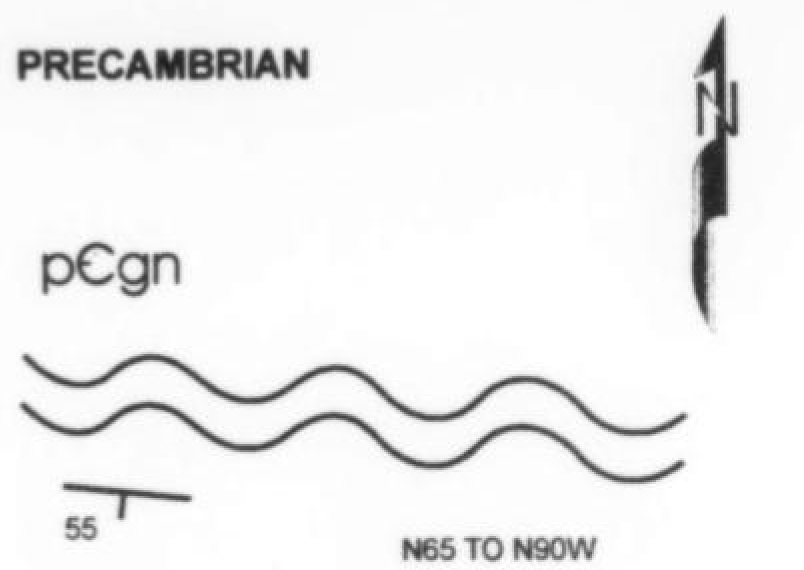
Structure

Three major structural trends are present in the vicinity of the Sweet Home mine, including (1) an early northwest to east-west fault and fracture-trend parallel to foliation and banding in the Precambrian gneiss, but with a steeper southerly dip, (2) a northeast fault trend, which contains the majority of the Ag-base-metal veins, and (3) a later, north-south-trending fault and fracture zone. All three structural trends contain both porphyry intrusions that are altered and mineralized. Hence, all structures are pre-mineralization. Traces of all stages of mineralization occur in the structures. There is evidence of minor movement throughout mineralization that resulted in opening and closing of structures during the various stages of hydrothermal activity. Strike-slip movements with left-lateral displacements of 1 to 2 feet are common, particularly on northeast and north-south structures. A later normal fault trend with displacements of similar magnitude was noted. Minor offsets of Tertiary intrusions and some veins indicate that some minor movement took place after mineralization.

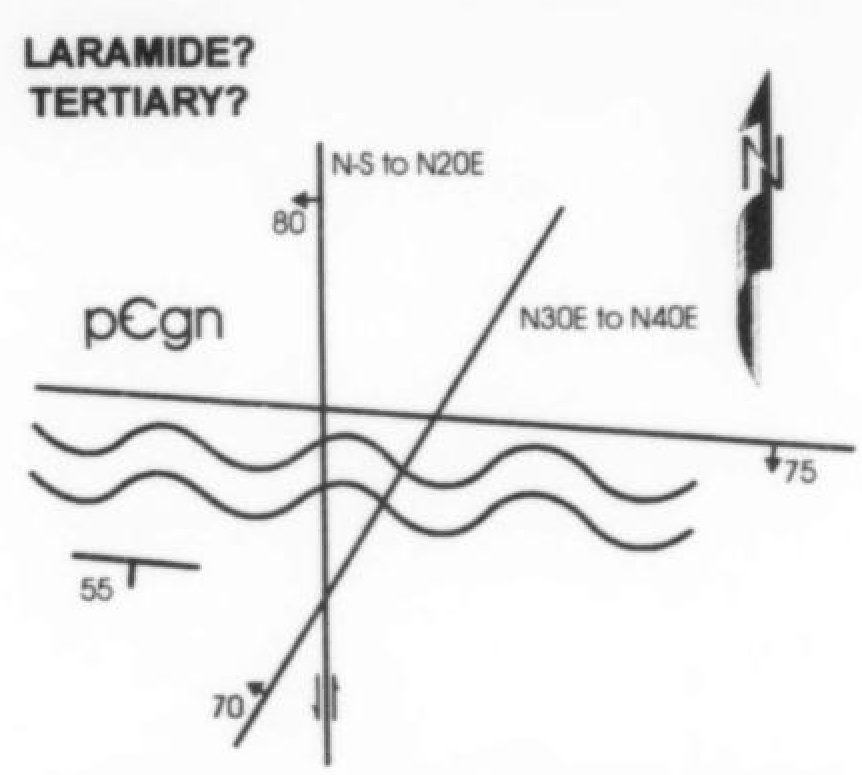
These events are best summarized by the following generalized sequence (Fig. 169): (a) Development of regional foliation and banding in granite gneiss took place in the Precambrian. (b) Development of fault and joint sets which strike parallel to, but dip steeper than, the regional foliation took place in the Laramide or Tertiary. Faults also developed in north-south and northeast directions. North-south structures generally crosscut both the northeast and east-west structures. (c) Intrusion of quartz monzonite porphyry took place in the Tertiary along east-west and north-south faults. Movement along north-south structures displaced east-west and northeast-trending structures. (d) "Greisen" and quartz-pyrite alteration of wall rocks, characterized by the development of quartz-pyrite-hübnerite veins with minor molybdenite (± fluorite in veins and alteration) that may be related to a large hydrothermal porphyry system at depth, took place in the Tertiary. Some movement continued along north-south and northeast-trending faults, opening void space for later base-metal crystal development. (e) Northeast veins were flooded with base-metal mineralization (Tertiary). During this stage, rhodochrosite crystal development occurred in open spaces near fault intersections along this structure.

The intersections of the various fault traces are commonly good targets for exploration. Irregularities and offsets of the fault planes created open space for potential pocket development.

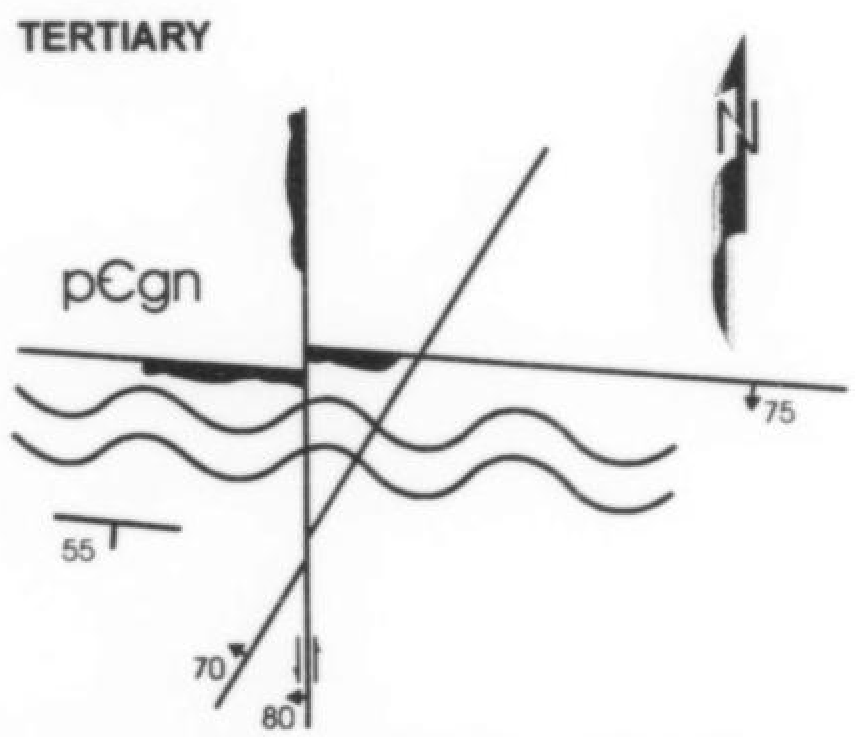
All combinations of structural intersections have been noted to cause deflections in strike or dip. However, the most productive pockets are located where northeast structures cross those that trend east-west (Coors Pocket, Main Stope pockets) or north-south structures cross northeast structures (Watercourse Raise) (Figs. 166, 167). Additional structural features that have caused widening of vein structures and pocket formation, although of less importance, include (1) opening of the steeper portion of veins with variable dip due to normal offset, (2) small scale sigmoid loops where the area within the loop is mineralized, and (3) local strike and/or dip deflections along a single vein due to refraction across host rocks of varying competency or fabric (i.e. anisotropic host rock). Most small pockets are of this latter type.



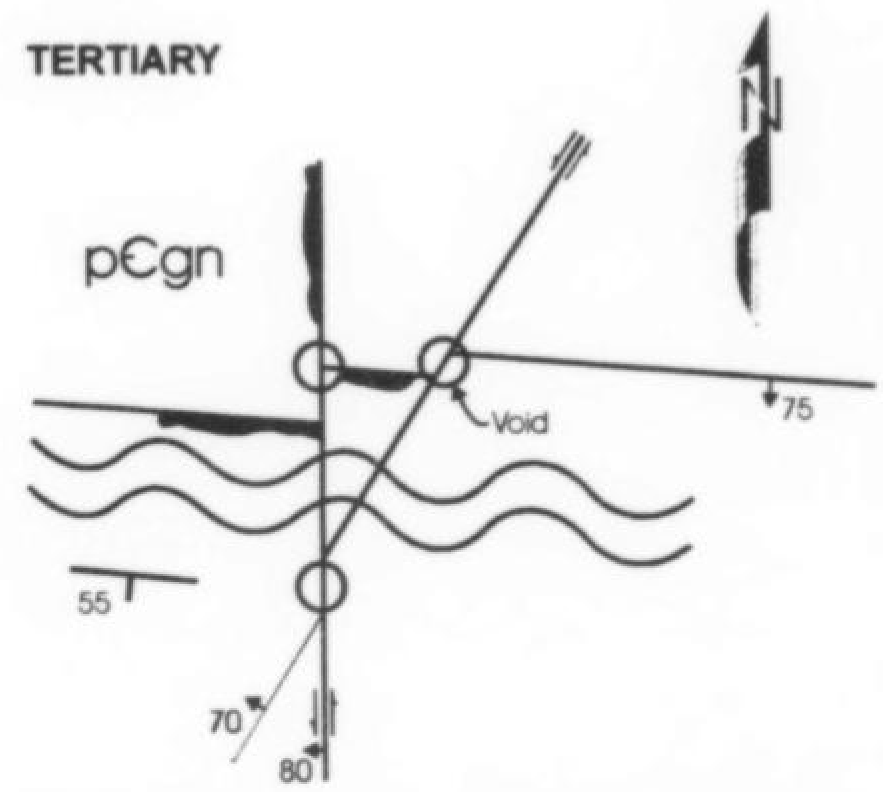
A. PreCambrian—Development of regional foliation. Banding occurs in granite gnesis with irregular biotite schist pods.



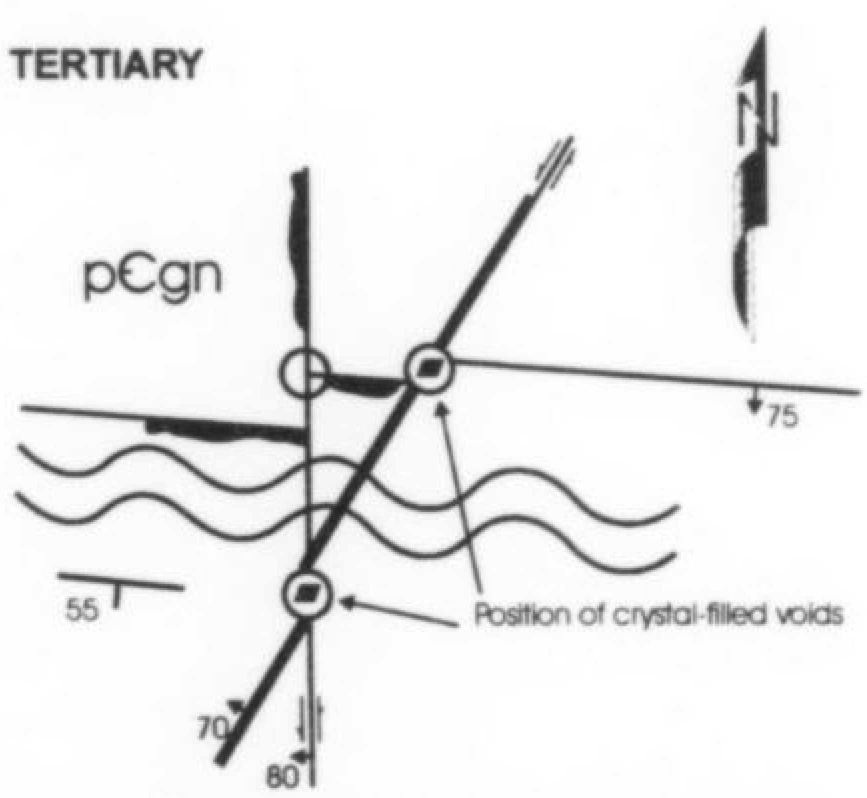
B. Laramide/Tertiary?—Development of E-W trending fault and joint sets which strike parallel to, but dip more steeply than, the regional foliation. Faults also developed in the N-S and N-E directions. N-S structures generally crosscut both the N-E and E-W structures.



C. Tertiary—Intrusion of quartz monzonite porphyry occurred along E-W and N-S trending faults. Movement along N-S structures displaced E-W and N-E trending structures.



D. Tertiary—Start of greisen and quartz-pyrite alteration of wall rocks characterized by the development of quartz-pyrite-hübnerite veins with minor molybdenum mineralization. These events may be related to a large hydrothermal porphyry system at depth. Continued movement along N-S and N-E trending faults opened voids for later base-metal crystal development.



E. Tertiary—N-E trending veins are flooded with base-metal mineralization (red). During this stage, rhodochrosite crystal development occurred in open spaces near fault intersections along this structure.

Figure 169. **Development of structure (foliation, banding, faulting, jointing, intrusions, veins and mineralization) in the Sweet Home mine area.**

Hydrothermal Alteration and Mineralization

All lithologic units exposed in the mine have been locally altered hydrothermally. Widespread areas of propylitic alteration are common, particularly in biotite-rich gneisses and schists—such zones are not directly related to veins. Disseminations and fracture/joint fillings of epidote-chlorite-pyrite-hematite are common. Widespread sulfidization of biotite to fine-grained pyrite is ubiquitous, and subsequent oxidation of this pyrite on the surface has resulted in brightly colored reds and yellows of the Red Amphitheater on Mount Bross above the mine.

Hydrothermal alteration directly related to vein mineralization is very pronounced in certain rock types at the Sweet Home mine. This alteration type consists of varying amounts of hydrothermal muscovite, pyrite, quartz and fluorite. In places quartz and pyrite may dominate along with fine-grained sericite. In such cases, the alteration type is best termed phyllic alteration. The more typical alteration type, however, consists of a mixture of coarse-grained, snow-white muscovite, fine-grained fluorite, pyrite and quartz. This alteration type commonly occurs as replacements of wall rock adjacent to early stage quartz-pyrite-fluorite ± hübnerite ± sphalerite veins and represents a greisen type of alteration. The common wall rock alteration minerals that form selvages around the veins also are found crystallized along the vein walls. Selvages of this alteration type are typically 1 to 5 inches in width, roughly equivalent to vein widths.

Greisen-type alteration of host rocks occurred early in the Sweet Home hydrothermal system, as part of the higher temperature sericite (muscovite)-fluorite-pyrite-quartz (with topaz inclusions—Wenrich, this issue; Reynolds, this issue)-hübnerite stage of vein mineralization. In fact, later-stage base metal-fluorite-rhodochrosite-stage veins that occupy structures that weren't open to the early, greisen stage of mineralization typically are bordered by fresh wall rocks with virtually no alteration selvages present.

Megascopically, veins of the Sweet Home system display a consistent paragenesis—readily identified from the simple banding from the vein wall inward, and locally from crosscutting relationships. A typical vein structure is 1 to 10 inches wide (wider structures are occasionally present in old stopes that were mined for metals). Early-stage white muscovite and fluorite (commonly looks orange on mine walls, but is actually light green when removed and cleaned) contain pyrite; these minerals grade from wall rock replacement into open-space filling along vein walls. Clear quartz crystals develop where open space is present, and crystals of hübnerite occur embedded in this quartz or occasionally as free-growing crystals. Fluorite typically occurs as pale blue or greenish cubes growing on early quartz crystals projecting inward from masses of muscovite rosettes intergrown with fluorite. Occasionally this muscovite or quartz will contain boxworks and cubic casts indicating an early period of pyrite or fluorite dissolution.

The earliest base-metal sulfide to crystallize was invariably black to green sphalerite. Well-formed crystals commonly grow on large, early pyrite cubes and octahedrons.

Copper mineralization followed, with varying amounts of associated tetrahedrite, chalcopyrite and bornite. Tetrahedrite and chalcopyrite form well-developed crystals whereas bornite occurs in masses. Chalcopyrite and tetrahedrite have been noted as crystals growing on early pyrite and sphalerite. In portions of the mine near the present erosional surface (less than 100 feet or so in depth) the chalcopyrite locally develops an attractive coating of malachite. The relative age of copper sulfide and other sulfides is unclear megascopically, but definitely post-dates sphalerite mineralization. Galena appears to partially overlap and post-date copper mineralization, and occurs as granular masses as well as cubes and modified octahedra. Other species of the sulfide-sulfosalt assemblage are not readily visible in hand specimen, except for bornite coatings on earlier sulfides.

The latest assemblage includes rhodochrosite and fluorite with local accumulations of apatite, barite and calcite as small crystals growing on any of the formerly discussed minerals. Rhodochrosite commonly forms the middle portion of banded veins, as massive pink material. However, within pockets rhodochrosite commonly takes on a redder color, particularly when the crystals are well-formed and isolated. These crystals commonly occur embedded over earlier, darker sulfides and sulfosalts, or nucleate around early quartz needles that penetrate the rhombohedrons. Fluorite, as purple and colorless or zoned crystals commonly occurs on rhodochrosite crystals (fluorite is the only mineral, in its varied colors and crystal habits, that crystallized throughout the entire paragenetic sequence).

Occasionally, pockets are encountered which contain one or all of the following: late, small green to blue apatite crystals, bladed white barite, and masses of whitish pink calcite, all of which have grown on earlier minerals, including the relatively late rhodochrosite-fluorite stage. Fine-grained white kaolinitic clay (dickite) fills the bottom of some pockets. Washing of this clay from the bottom of many pockets may yield loose crystals of any of the hypogene assemblages described. Near-surface pockets of this material commonly contain brown, tan and black mud caused by limonite and manganese-oxide staining of the dickite clay.

The paragenesis of minerals in the Sweet Home mine can be interpreted to represent an early, higher-temperature suite (magmato-hydrothermal) containing greisen-alteration and local fluorine-tungsten mineralization followed in time by a base metal-rhodochrosite-phosphate-sulfate-carbonate stage that is later, usually superimposed on the early stage, and probably represents a dilution of early high-temperature fluids by cooler, more dilute meteoric water through time.

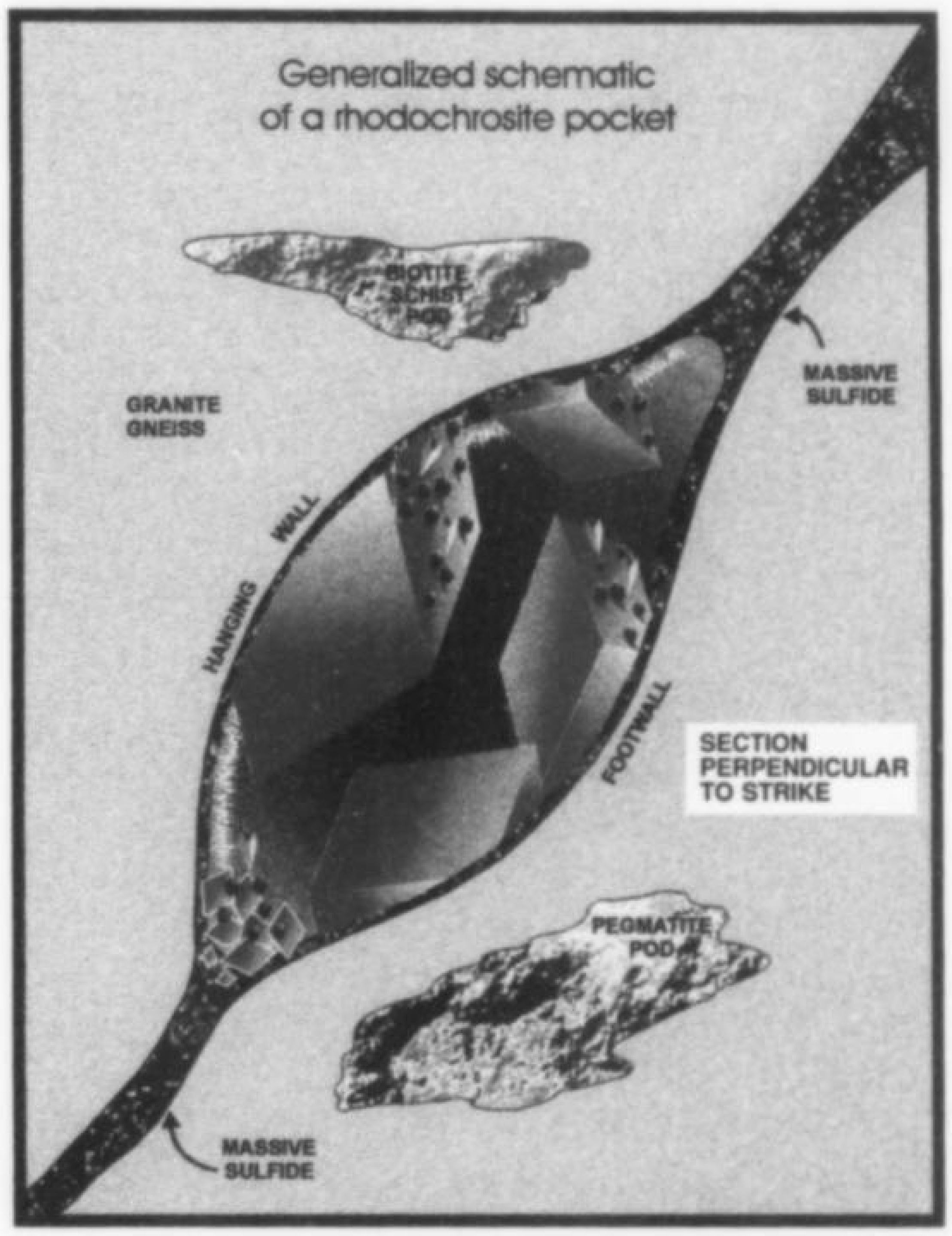


Figure 170. **Generalized schematic drawing of a typical rhodochrosite pocket.**

STABLE ISOTOPE ANALYSIS: THE ORIGIN OF THE ORE FLUIDS

To better determine the origin of the ore fluids at the Sweet Home mine, we chose several samples for oxygen isotope analyses and one for hydrogen isotope analysis. Oxygen and hydrogen isotope data have been useful in determining the source of ore fluids in a wide variety of hydrothermal ore deposits (Taylor, 1974). Common sources of fluids that typically form ore deposits are magmatic water, meteoric (rain) water, sea water, and connate or formation water. Frequently, mixtures of one or more fluid types are involved in the process of ore deposit formation, and to delineate the fluid evolution, many samples of different minerals must be analyzed. That was not possible here due to the constraints of a limited research budget. However, the data can be interpreted within the context of other studies, including the geologic mapping, fluid inclusion systematics, mineralogic determinations, and geochemistry. Assimilated with other data, the stable isotope analyses provide refinement for a Sweet Home mine vein mineralization model.

Choice of Samples

Reynolds (this issue) suggests, on the basis of fluid inclusion data, that early-stage quartz-pyrite-sericite-hübnerite veins were deposited at minimum temperatures of 360° to 370°C from a fluid that was dominantly of magmatic origin. Slightly later mineral assemblages characterized by the occurrence of Cu, Zn, Pb and Ag sulfides and sulfosalts, with associated rhodochrosite, fluorite, apatite, etc., were deposited at temperatures of 260° to 305°C. The early gem-rhodochrosite was deposited at temperatures of 280° to 310°C from fluids that were slightly diluted with meteoric water. Together, these stages represent an early, magma-dominated, high-temperature stage of hydrothermal activity at Sweet Home. To examine this suggestion we chose three samples. The first was a quartz-pyrite-sericite-hübnerite vein sample from near the Coors Pocket along the main vein, second crosscut. The second sample was from the Watercourse Drift, third crosscut, and consisted of a vein hosted in pegmatite, that contained sphalerite, tetrahedrite, pyrite, galena, covellite, chalcopyrite, bornite, molybdenite and rhodochrosite, along with minor quartz. The third sample was a gemmy rhodochrosite from the Watercourse Vein, that has all the characteristics of the early, high-temperature stage of rhodochrosite.

The samples were prepared and analyzed by Geochron Laboratories. Analytical data and descriptions of the veins are included in Table 3.

INTERPRETATION

The minerals in Table 3 were deposited by an ore fluid, which was dominantly magmatic water, at temperatures that were measured by the fluid inclusion analyses discussed by Reynolds (this issue). Because of crystal-chemical processes, when water deposits

Table 3. **Stable isotope analyses of minerals from the Sweet Home mine.**

Sample No.	*Location and Type*	*Mineral*	*δ18O*	*δD*
95SH01	Main Vein, near Coors Pocket, quartz-pyrite-sericite-hübnerite vein	Quartz Muscovite	+13.3	 −116
94SH01A1	Watercourse Vein Sulfide-rhodochrosite	Quartz	+11.3	
4BL94	Watercourse Vein Gem rhodochrosite	Rhodochrosite	+11.2	

Analyses relative to SMOW standard.

minerals such as quartz, muscovite and rhodochrosite, there is a fractionation of the oxygen and hydrogen isotopes between that water and the mineral. That fractionation produces differences in the isotopic composition of the water and the mineral, and these differences are temperature-dependent. The mineral-water fractionations have been determined experimentally, and it is possible to calculate the isotopic composition of the water if two factors are known: (1) the isotopic composition of the mineral, which is provided in Table 2, and (2) the temperature of mineral deposition, which was measured by the fluid inclusion analyses. The isotopic composition of the ore-fluid water was calculated from the data in Table 2. The results are shown in Table 4.

Table 4. **Calculated oxygen and deuterium isotope composition of Sweet Home ore fluid.**

Sample No.	*Mineral*	*Temperature (°C)*	*δ18O (‰)*	*δD (‰)*
95SH001	Quartz	370°	+8.5	
	Muscovite	370°	+7.7	−82
94SH01A1	Quartz	300°	+4.4	
4BL94	Rhodochrosite	300°	+5.6	

Temperatures were calculated from maximum fluid inclusion filling data. However, these temperatures are uncorrected for pressure, which would increase them. See Reynolds (this issue).

In most studies of this type, many samples from each stage of mineralization are analyzed and a range of isotopic compositions for fluids at each stage are derived from the calculations. This range of composition is then compared to isotopic compositions of ore fluids from various types of deposits, whose fluid origins are known. We cannot do that unequivocally at the Sweet Home due to lack of data, but we can say that the results of our calculations from the isotope data conform well to the synthesis of Reynolds (this issue) based on fluid inclusion measurements.

The Sweet Home oxygen isotope composition of early-stage ore fluid that deposited quartz-pyrite-sericite-hübnerite veins is about +8‰. This composition falls within the range for water of magmatic origin (Taylor, 1974). The deuterium composition of the fluid, calculated from the muscovite δD, is approximately −80‰, which overlaps the rather broad range of magmatic water composition (Taylor, 1974). The oxygen isotopic composition of the water that deposited the quartz and rhodochrosite from the sulfide-rhodochrosite veins is in the range of +4.5 to +5.5‰. A fluid of this composition could be one of dominantly magmatic origin, with a component of meteoric water of perhaps 10 to 20%.

These calculated fluid compositions are compatible with Reynolds' (this issue) synthesis of fluid evolution and essentially confirms that early stages of mineralization at Sweet Home, including the deposition of the gem-rhodochrosites, took place in a high temperature, magmatic-dominated hydrothermal system that was just beginning to experience an influx of meteoric fluid. Our preferred interpretation is that Sweet Home is a distal part of a Climax-type Mo-porphyry system, for reasons listed earlier. The mineralogy and geochemistry of the Sweet Home veins are similar to those found in the periphery of the Climax-type systems, including the presence of Mo, W and F contents. The geologic evidence strongly suggests an association with this type of system (see Reynolds, this issue), although most likely at some distance from its center (Fig. 171).

GEOCHRONOLOGY

The results of geologic mapping, structural analysis, fluid-inclusion measurements, mineralogic studies, and isotope analyses have constrained the conditions of origin of the Sweet Home deposits, and identified the likely sources of ore fluid. However, a separate method, K-Ar geochronology, is needed to determine when the mineralization occurred, and how it was related to regional and local, or district-scale events.

Sweet Home veins, both the quartz-pyrite-sericite-hübnerite and

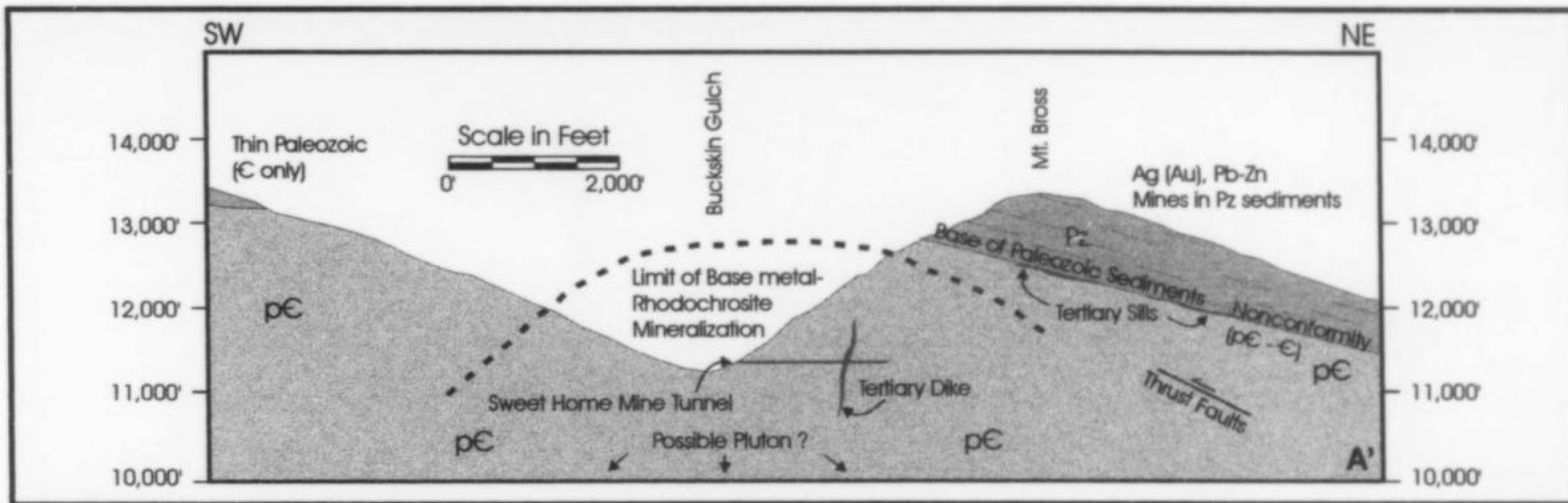


Figure 171. **Generalized geologic cross-section through the Sweet Home mine area.**

Explanation

Pz — Paleozoic - Cambrian through Pennsylvanian clastic and dolomitic sediments intruded by Tertiary dikes and Sills

pЄ — Precambrian Granite Gneiss, schist, granodiorite, migmatite and pegmatite intruded by Laramide to Tertiary dikes and plugs

SWEET HOME MINE
ALMA
COLORADO

sulfide-rhodochrosite types, are surrounded by halos of sericitic alteration, referred to earlier in this paper as greisen alteration. This alteration replaces, to a greater or lesser degree, feldspars and biotite in the wall rock with sericite, some of it quite coarse-grained. Because this alteration only occurs around the veins, it must have formed when the veins were deposited. Sericite is a potassium-bearing mineral, and it can be dated by the K-Ar isotopic method, which has been widely applied to the determination of the age of hydrothermal mineralization and alteration (Silberman, 1983).

Table 5. **K-Ar analytical data and isotopic ages of vein selvages from the Sweet Home mine.**

Sample No.	*Location and vein type*	*K (%)*	*40Ar* (ppm)*	*Age*
92SH01	Crosscut No. 3. N30E. Quartz-pyrite-sericite-hübnerite and sulfide-rhodochrosite vein.	8.81	0.0188	30.6±0.8
92SH02	Watercourse vein. EW structure. Quartz-pyrite-sericite-hübnerite vein.	6.81	0.0131	27.6±0.7
92SH03	Crosscut No. 2. Sulfide-rhodochrosite vein.	7.10	0.0152	30.6±0.8

*Refers to radiogenic argon-40 content.

Three samples of sericite-altered wall rock, each adjacent to veins, were selected from different sites in the Sweet Home mine. All samples were so pervasively altered that they contained a minimum of 40% sericite. The rocks were crushed and sericite was concentrated using standard mineral separation techniques. The sericites were dated by K-Ar isotopic techniques by Geochron Labs. Analytical results and isotopic ages are shown in Table 5.

The K-Ar ages indicate that the Sweet Home veins were emplaced approximately 30 million years ago. Hydrothermal activity occurred over a span of about 3 million years. It is not possible to distinguish ages of the various stages of vein mineralization. The data suggest that for two veins, a combined quartz-pyrite-sericite-hübnerite and sulfide-rhodochrosite vein, and a sulfide-rhodochrosite vein, the isotopic age is essentially the same. Another vein, a quartz-pyrite-sericite-hübnerite one, was slightly younger. More likely, the system pulsed, and produced multiple cycles of mineralization, caused by multiple pulses of magma injection. It is likely that any individual vein, regardless of type, would give an age near those shown in Table 5. This is the most common result of detailed studies of this type of system (Silberman, 1983).

These isotopic age data are a further indication of the association of Sweet Home mineralization with porphyry-Mo system evolution in the region. K-Ar and fission track geochronology at Climax indicate emplacement of rhyolite and granite bodies hosting or related to mineralization from between 33 and 25 million years (White and others, 1981), with the most likely time span for major mineralization being 30 to 25 million years. Climax is about 5 miles northwest of Sweet Home. Veins essentially identical to those at Sweet Home occur peripheral to Climax (White and others, 1981). Drilling for porphyry molybdenum in Buckskin Gulch at Mount Bross was carried out during the 1970's by AMAX.

The complex and variable styles of mineralization in the Alma district described earlier appear to be constrained by K-Ar and fission track ages of pre- and post-mineralization dikes to the time period 35 to 25 million years ago (Bookstrom, 1990). Molybdenum mineralization at Red Mountain, Urad-Henderson took place about 28 to 23 million years ago (Bookstrom, 1990). In all of these nearby systems, multiple stages of intrusion and hydrothermal mineralization occurred over a significant time span, during which Sweet Home was also active. Hydrothermal activity at Sweet Home is thoroughly concordant with similar activity taking place in the northern part of the Central Colorado Mineral Belt. Rhodochrosite is not all that rare throughout the entire region. It just happens to be of spectacular quality at the Sweet Home mine, which leads one to the question—could there be more of it elsewhere, nearby?

Table 6. **Minerals identified from the Sweet Home mine since 1992.**		
Native Elements		
Copper	Cu	Hurlbut, personal communication, 1994
Sulfides		
Bornite	Cu_5FeS_4	Honea, 1992; Lees, 1995; Wenrich and Aumente-Modreski, this issue
Chalcopyrite	$CuFeS_2$	Honea; 1992; Lees, 1995
Covellite	CuS	Lees, 1995
Digenite	Cu_9S_5	Honea, 1992
Galena	PbS	Modreski, 1988; Honea, 1992
Greenockite	CdS	Lees, 1995
Mawsonite	$Cu_6Fe_2SnS_8$	Hofmann, personal communication, 1994
Molybdenite	MoS_2	Misantoni and Lees, personal communication, 1993
Pyrite	FeS_2	Honea, 1992; Lees, 1995; Wenrich and Aumente-Modreski, this issue
Sphalerite	$(Zn,Fe)S$	Honea, 1992; Lees, 1995; Wenrich and Aumente-Modreski, this issue
Stromeyerite	$AgCuS$	Honea, 1992; Wenrich and others, 1995
Spionkopite	$Cu_{39}S_{28}$	Wenrich and Aumente-Modreski, this issue
Sulfosalts		
Tetrahedrite/Tennantite	$(Cu,Fe)_{12}(Sb,As)_4S_{13}$	Honea, 1992; Wenrich and others, 1995
Unknown		Modreski, personal communication, 1995
Oxides		
Dickite	$Al_2Si_2O_5(OH)_4$	Lees, 1995; Modreski, personal communication, 1995
Ferrimolybdite	$Fe_2(MoO_4)_3 \cdot 8H_2O$	Misantoni and Lees, personal communication, 1993
Halides		
Fluorite	CaF_2	Lees, 1995
Carbonates		
Calcite	$CaCO_3$	Lees, 1995
Dolomite	$CaMg(CO_3)_2$	Honea, 1992
Malachite	$Cu_2(CO_3)(OH)$	Modreski and Foord, personal communication, 1994
Rhodochrosite	$MnCO_3$	Lees, 1995
Phosphates		
Fluorapatite	$Ca_5(F,Cl,OH)(PO_4)_3$	Lees, 1995
Goyazite	$SrAl_3(PO_4)_2(OH)_5 \cdot H_2O$	Ranstrom, personal communication, 1994; Hlava, personal communication, 1994
Svanbergite	$SrAl_3PO_4SO_4(OH)_6$	Ranstrom, personal communication, 1994; Hlava, personal communication, 1994
Triplite	$(Mn,Fe,Mg,Ca)_2(PO_4)(F,OH)$	Wenrich and Aumente-Modreski, this issue
Tungstates		
Hübnerite	$MnWO_4$	Lees, 1992; Wenrich and others, 1995
Silicates		
Chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$	Foord and Murphy, personal communication, 1994
Mica group minerals		Honea, 1992; Lees, 1995; Wenrich and Aumente-Modreski, this issue
Quartz	SiO_2	Lees, 1995
Topaz	$Al_2(OH,F)(SiO_4)$	Lees, 1995; Wenrich and Aumente-Modreski, this issue
Sulfates		
Anglesite	$PbSO_4$	Hurlbut, personal communication, 1995
Barite	$BaSO_4$	Lees, 1995

MINERALOGY

MINERALS OF THE SWEET HOME MINE

Jack A. Murphy
Curator of Geology
Denver Museum of Natural History
2006 Colorado Boulevard
Denver, Colorado 80206

James F. Hurlbut
Department Associate
Department of Earth Sciences
Denver Museum of Natural History
2006 Colorado Boulevard
Denver, Colorado 80206

INTRODUCTION

This article describes the minerals from the Sweet Home mine, with emphasis on the crystallized specimens discovered during mining operations between 1991 and 1996. For details on electron microprobe analysis, petrographic identifications, fluid inclusion salinities, and geochronology, see other papers in this issue (Wenrich and Aumente-Modreski; Wenrich; Reynolds; and Misantoni *et al.*). Minerals reported and confirmed from the mine are discussed in the following pages; they are listed and cross referenced as to source in Table 6. Many other minerals have been reported from the mine, but have not been confirmed.

The mineral associations that typically occur in Sweet Home mine specimens are discussed, but mineral paragenesis is not. The species described are from the copper-antimony-tungsten-silver-base-metal sulfide veins in Precambrian granite-gneiss host rock.

About a dozen metallic vein minerals are known, comprising a suite of common base-metal sulfides and one main sulfosalt, tetrahedrite-tennantite. The occurrence of hübnerite adds to the variety of minerals found; one sparse tin mineral (mawsonite) has also been found. Many of the uncommon to rare sulfides and sulfosalts known elsewhere in Cu-As-S veins have not, as yet, been identified at the Sweet Home mine. Spionkopite has been identified by electron microprobe (Wenrich and Aumente-Modreski, this issue), and another sulfide, tentatively identified as eclarite or miharaite, is under investigation. Minerals that are part of the massive ore assemblage identified by petrographic techniques and described by Honea (1992) and Wenrich and Aumente-Modreski (this issue), in general have also been identified as euhedral crystals in hand specimens, with the exception of stromeyerite, which has not yet been seen in hand specimens. Gangue minerals represented in the veins are common species, and, except for the rhodochrosite which occurs in superior large crystals, calcite, quartz and associated species occur in smaller, well-formed crystals.

What is noteworthy about the minerals from the Sweet Home mine is not so much the frequency of the occurrence of a particular species, as the excellence of the crystals. Superb specimens with impressive euhedral crystals have been recovered, many with three to four different species in association. Many such specimens, which were carefully collected during the mining operation led by Bryan Lees from 1991 to 1997, currently enhance collections around the world.

PREVIOUS STUDIES

Sweet Home mine minerals have long been recognized and reported in the literature, but few, if any, details about them were published. One of the earliest mineral reports is by Endlich (1878), a geologist on the F. V. Hayden expedition to Colorado in 1876. Eight entries in his *Catalogue of Minerals Found in Colorado* are: cuprite, fluorite, jamesonite, melanterite, rhodochrosite, tetrahedrite, tennantite and zinkenite. The reports were reiterated by Smith (1883). The Alma locality was not mentioned by Kunz (1887), who described superb transparent crystals of rhodochrosite from the John Reed mine at Alicante, Lake County, Colorado. The Sweet Home mine and the Tanner Boy mine were mentioned together by Dana (1898), but rhodochrosite was reported only from the Tanner Boy.

The first comprehensive regional geologic studies of the Alma district (Patton and others, 1912; Butler, 1912) gave little information about the Sweet Home mine, and the mine is not mentioned in Henderson (1926). The early belief that argentiferous galena was the source for silver in the mine (galena has since been shown to be only one minor mineral of several that is the source for silver, Wenrich and Aumente-Modreski, this issue) was reinforced by Patton and others (1912); they also listed rhodochrosite, cuprite, enargite, bornite, azurite, malachite, and fluorite from the mine.

The Sweet Home mine rhodochrosite crystals have overshadowed reports of the other species from the mine (Caplan, 1936). Little information is found in standard mineralogical references. For example, two noteworthy species known from the mine, tetrahedrite/tennantite and hübnerite, are not listed in Palache and others (1944, 1951), or by Eckel (1961). Roots (1951a,b) reports collecting rhodochrosite and pyrite at the Sweet Home mine.

Selected mineralized areas of the Alma district have been described in the geological literature (Butler and Singewald, 1940; Singewald, 1932, 1947; Singewald and Butler, 1931a,b, 1933, 1941; Vanderwilt, 1947; Pierson and Singewald, 1953; and Del Rio, 1960). However, none of these detail the Sweet Home mine.

A few articles appeared in the popular literature after World War II (Roots, 1951a,b; Ingle, 1958; Miller, 1971), but the mine was closed during most of this time. The first extraordinary rhodochrosite discoveries were made in the 1960's (Bancroft, 1973, 1984). Some geological investigations of the district were conducted (Corn, 1957); however, much of the emphasis on minerals and mining in this part of Colorado was associated with the Climax molybdenum mine, 5 miles to the northwest in Lake County. When the Climax mine was operating, good specimens of pyrite, fluorite and rhodochrosite were occasionally available (Kosnar and Miller, 1976). Mineral specimens were not readily available from the Sweet Home mine until 1978, when the mine was reopened by Richard Kosnar (Kosnar, 1979a,b).

RECENT ACTIVITY

Much attention has been focused on the Sweet Home mine since Bryan Lees reopened it in 1991 (Voynick, 1992, 1994a,b; Cook, 1993; Kile and Lees, 1993a,b; Robinson, 1993; Smith, 1993; Moore, 1993; Senecal, 1994; Dempsey and Voynick, 1994; Lees, 1994; Murphy, 1994, 1997; Wenrich and others, 1995; and Frazier and Frazier, 1996). Specialized mining techniques and methods of extracting specimens have been developed and employed at the mine, facilitating the discovery and preservation of previously unsurpassed specimens. The highlight of rhodochrosite discoveries is the Alma King, a 5½ by 6½-inch, bright red rhombohedron on a plate of quartz crystals with six associated mineral species (Moore, 1993; Murphy, 1994). Access to old and new underground workings at the Sweet Home mine during this time has stimulated mineralogical and geological research by contributing to a better understanding of Colorado Mineral Belt base-metal veins and associated structures.

MINERALS

The following mineral descriptions focus on the euhedral minerals that are found on Sweet Home specimens that have been widely distributed since the mine reopened in 1991. Some historical information on minerals reported from the Alma district is also included. Information below includes new data on material collected between 1991 and 1995, and, wherever possible, is based on X-ray diffraction or electron microprobe results. Research on Sweet Home mine minerals continues as new material is encountered. Only a few mineral species new to the Sweet Home mine have been identified since 1990. Some minerals have not been adequately studied, for example carbonates other than rhodochrosite, and the various dark-colored stains or coatings that are common on many specimens.

Anglesite $PbSO_4$

Anglesite was identified by X-ray diffraction on samples collected by J. F. Hurlbut in 1994. Several specimens were collected from a sericite sheer zone in Crosscut No. 2. The anglesite is in thin, 3–5 mm, compact and massive bands along with dickite, brown fluorite, green fluorite and quartz. There are no distinct individual crystals on the examined samples.

Barite $BaSO_4$

Barite occurs sparingly in many of the mineralized pockets encountered during 1993 to 1995. In one sample, a 6-mm blade of a white, opaque barite grew before or with blue fluorite crystals. Barite from the Sweet Home needs to be studied further.

Bornite Cu_5FeS_4

Bornite appears to be more prevalent in certain veins of the mine than originally thought. It is a component of a late-stage of mineralization that coats other sulfides. Bornite was reported from the mine by Corn (1957), and at two other nearby places, namely, the Wyandotte property north of Kite Lake and on an unnamed mine dump southeast of the Sweet Home mine.

Bornite from the Sweet Home mine is probably best known from the Tetrahedrite Drift in an area mined during 1993. Bornite crystals and encrustations also occur on specimens taken from the Colorado Springs Pocket in July 1992. The bornite usually forms as isolated and intergrown subhedral, rounded crystals up to 8 mm across that usually range in color from deep blue to black. However, bornite also occurs as a blue to purple iridescent metallic coating on tetrahedrite/tennantite and sphalerite. Occasionally the surface of bornite exhibits an attractive silky bronze color thought to be an oxidized crust over dark blue to black massive material that has a conchoidal fracture on broken edges. This surficial material could be confused with chalcopyrite if not examined carefully; it may range from a deep golden bronze color to a darker, deep brown color. Bornite encrustations and microscopic crystals are commonly found on black sphalerite. Microprobe analyses of bornite are reported in Wenrich and Aumente-Modreski (this issue).

Calcite $CaCO_3$

Calcite was relatively unknown from the Sweet Home mine until pale yellow, intergrown crystals were encountered in the Tetrahedrite Drift in 1992. The calcite does not form in typical well-defined crystals; rather, the crystals are modified and intergrown rhombohedra. Calcite occurs in pockets within selected veins with other well-crystallized species, especially rhodochrosite. The plate containing the large Alma King rhodochrosite contains representative yellow calcite growth.

Chalcopyrite $CuFeS_2$

Chalcopyrite is a common mineral in the veins and occurs as small crystals on many specimens. As far as is known, the finest specimens came from a small vug located above the Rainbow Pocket, the location of the Alma King rhodochrosite crystal. Sharp, lustrous crystals up to 1 cm were found on a sulfide and quartz matrix. Microprobe analyses of chalcopyrite are presented in Wenrich and Aumente-Modreski (this issue).

Chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2$

A pale greenish blue mineral, occurring in veinlets and as coatings on massive quartz and sulfide was originally thought to be turquoise but proved to be chrysocolla (E. E. Foord, written communication, 1994). This material was found on the mine dump and has not been seen underground.

Copper Cu

Native copper was identified by Jim Hurlbut in sulfide-rich specimens dominated by black coatings on tetrahedrite and bornite. It occurs as very microscopic wires and irregular growths intimately associated with the black surface coatings, and as small, skeletal pore fillings. The material may be pseudomorphous after an unknown mineral.

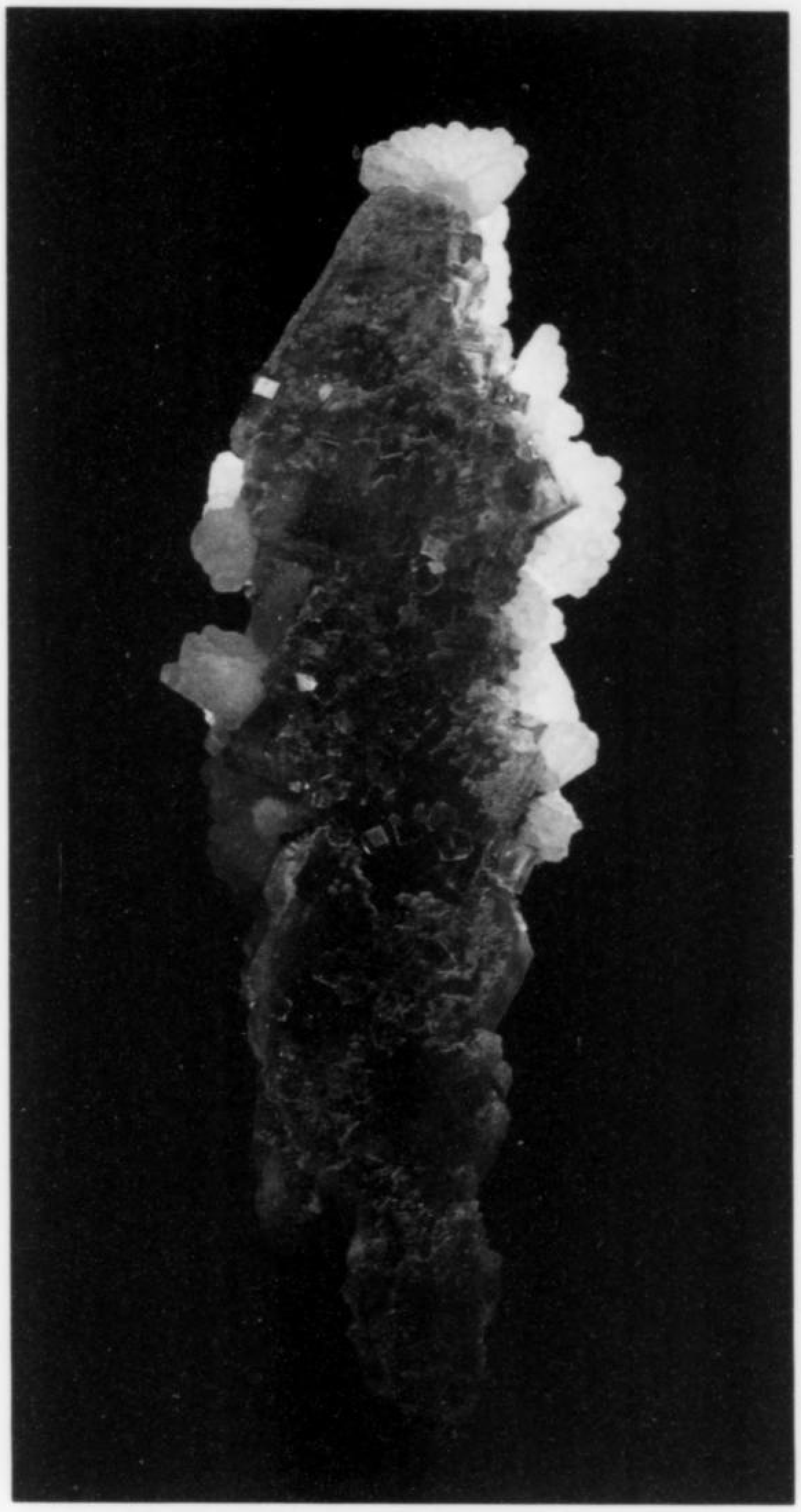


Figure 172. **Calcite and fluorite on rhodochrosite, 2.2 cm wide. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

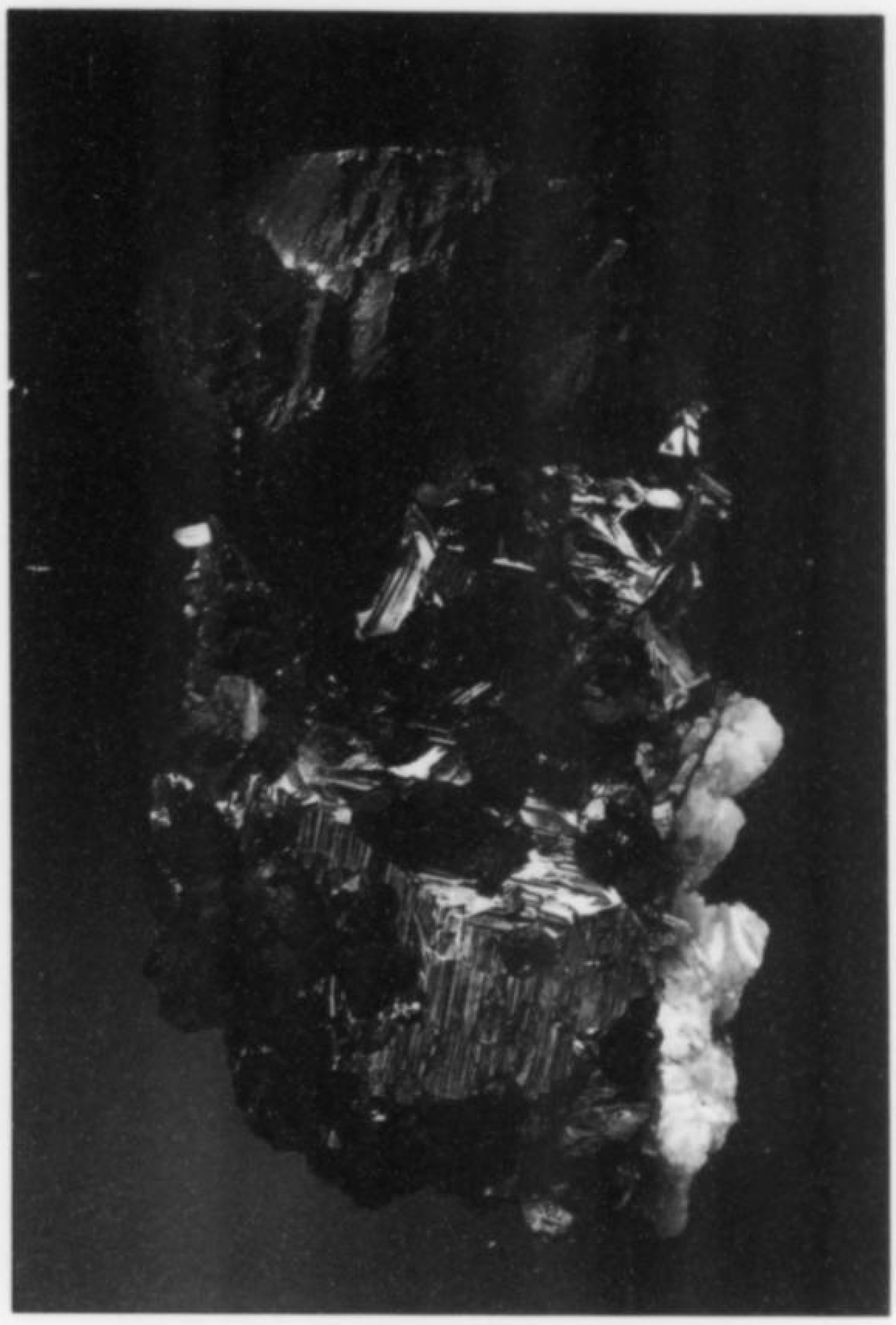


Figure 173. **Chalcopyrite crystals with quartz and sphalerite, 5.1 cm high. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

Covellite CuS

Covellite is mainly a fine-grained constituent of the sulfide ore and is primarily recognized in petrographic analysis (Honea, 1992). Some of the blue to purple coatings on sulfides may be covellite; however, little specific analysis has been done. Several crystals that petrographically resemble covellite were analyzed by K. J. Wenrich with the electron microprobe and determined to be spionkopite (this issue).

Dickite $Al_2Si_2O_5(OH)_4$

Microcrystalline pseudohexagonal platelets of dickite about 10 microns in diameter and 1–2 microns thick have been confirmed by XRD and SEM-EDS analysis by Peter J. Modreski (personal communication, 1992) and electron microprobe analyses by K. J. Wenrich (this issue). Dickite forms the bright white clay material that is found coating rhodochrosite and fluorite in the crystal pockets; it occurs widespread in the quartz-bearing and sulfide-bearing veins.

Digenite Cu_9S_5

Digenite has been reported by petrographic (Honea, 1992) and electron microprobe analyses (Wenrich and Aumente-Modreski, this issue). Digenite, verified by microprobe, was found in association with bornite and spionkopite. Some of the dark coatings on sulfide matrix with bornite might also prove to be digenite.

Dolomite $CaMg(CO_3)_2$

Only minor amounts of dolomite have been seen at the Sweet Home mine. So far as is known, no well-formed crystals have been found. According to Singewald and Butler (1941), iron-bearing dolomite was the most abundant gangue in the silver-lead ores of the Alma district; however, most of the mineral deposits discussed by these authors are replacement bodies in limestone where sphalerite and galena are abundant, pyrite is less so, and chalcopyrite and argentiferous tetrahedrite occur in small amounts. Dolomite was reported by them to contain much iron and some manganese, and was thought to be the most abundant gangue in quartzite-hosted gold deposits. Wells (1937) gave an analysis of carbonate gangue from the Orphan Boy mine that showed it was iron-bearing dolomite, not ankerite, as previously reported.

Ferrimolybdite $Fe_2(MoO_4)_3 \cdot 8H_2O$

Pale yellow coatings of ferrimolybdite occur with traces of visible molybdenite in quartz in a few places in the mine, especially the Watercourse Raise. These two minerals are also found in a quartz vein in an old drift that is about 250 feet northwest of the

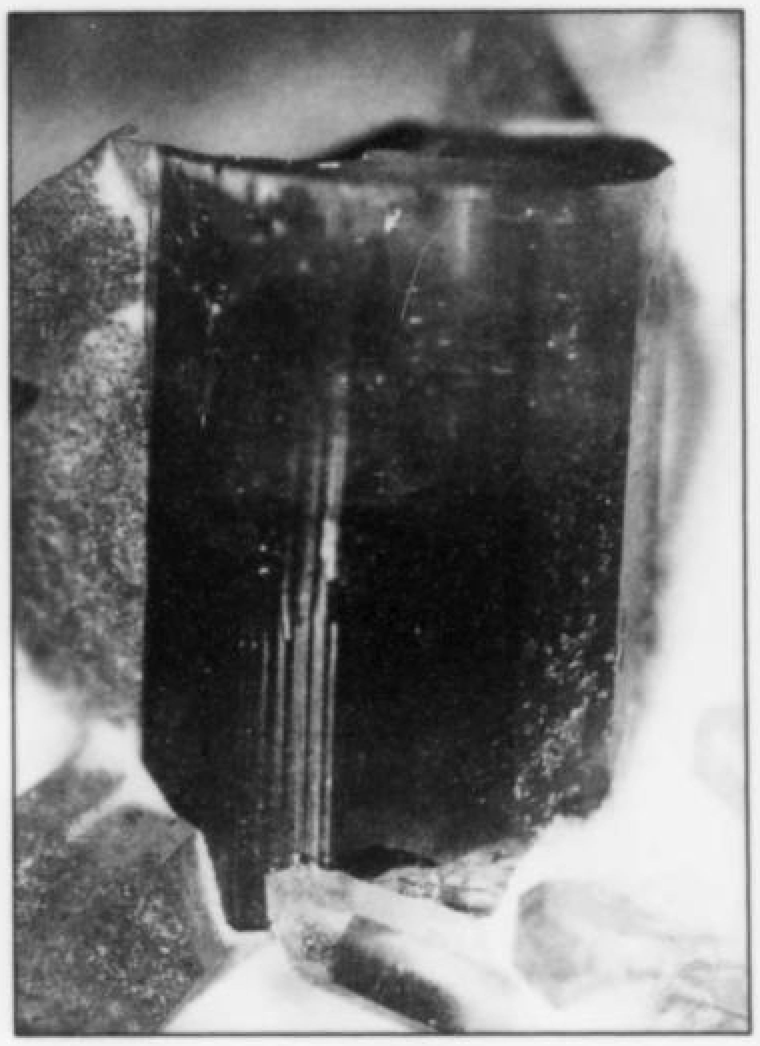


Figure 174. **Fluorapatite with color zonation, 5.5 mm. Denver Museum of Natural History collection; photo by Jack Thompson.**

Figure 175. **Fluorite cubes on quartz, 7.1 cm wide. Sweet Home Rhodo, Inc. specimen; Jeff Scovil photo.**

present portal of the Sweet Home mine (Bryan Lees and Dean Misantoni, personal communication, 1994).

Fluorapatite $Ca_5(PO_4)_3(F,Cl,OH)$

Attractive, pale greenish blue fluorapatite crystals are found sparingly in most veins in the Sweet Home mine. They are one of the more desirable crystallized species from the mine, especially as thumbnails and micromounts. Analysis by Wenrich (this issue) establishes the species to be fluorapatite; however, older literature refers to the mineral generally as apatite. Fluorapatite is found directly on rhodochrosite and other minerals, and commonly occurs as transparent, doubly terminated crystals. The largest crystals seen measure about 1 cm. Typically small clusters of crystals are found with rhodochrosite and needle quartz. Fluorapatite crystals are intimately associated with white dickite in pockets and may occur as "floaters" in this clay. Many small fluorapatite crystals may be lost when cleaning this clay off of sulfide specimens. The fluorapatite fluoresces an attractive pink color in shortwave ultraviolet light.

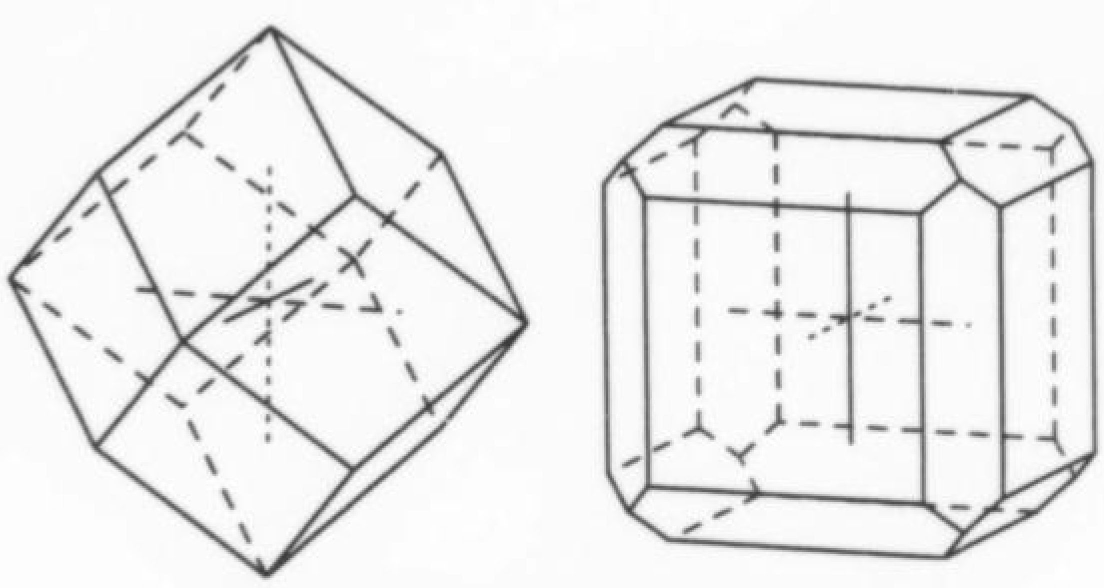


Figure 176. **Fluorite crystal habits common in the Sweet Home mine: dodecahedron *(left)* and cube-dodecahedron combination *(right).***

Fluorite CaF_2

Fluorite occurs at the Sweet Home mine as a gangue mineral throughout the various vein structures. In different parts of the mine fluorite appears in many colors, from colorless to yellow, blue, green, purple and brown. Layers of colored fluorite crystals seldom reach 2.5 cm in thickness, and are sometimes interleaved with dickite and sericite. In some of the pockets it appears that fluorite crystals grew during different periods of mineralization, as evidenced by zonation consisting of multiple layers of fluorite of different colors. Analysis of fluorite by Wenrich (Wenrich and Aumente-Modreski, this issue) shows gradational wispy changes in color, possibly due to changes in the mineralizing fluids.

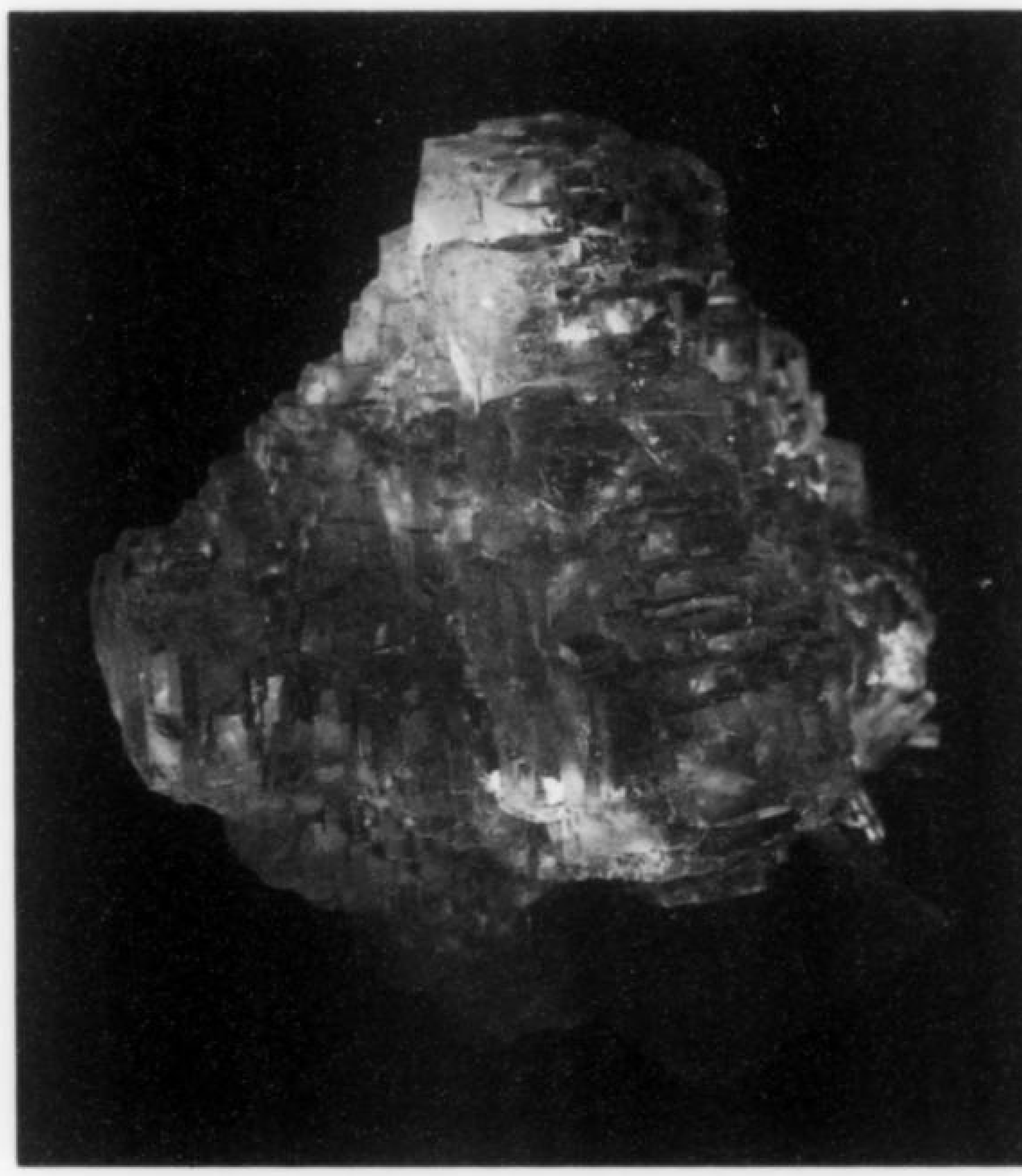


Figure 177. **Fluorite octahedron made up of intergrown cubes; 3.3 cm wide. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

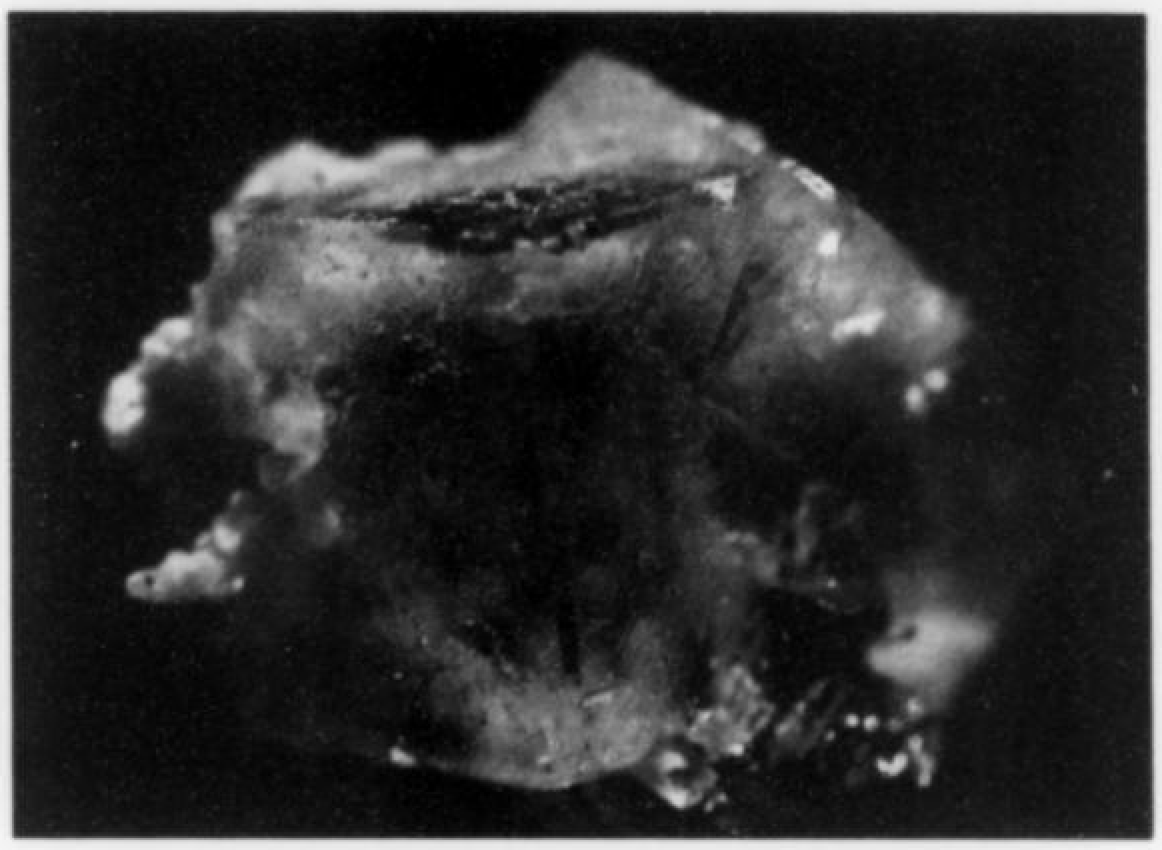


Figure 178. **Fluorite penetration twin, 5 mm. Denver Museum of Natural History collection; photo by Jack Thompson.**

The predominant fluorite crystal shape is the cube truncated by dodecahedron faces (Fig. 176 right). A few nearly perfect dodecahedrons have been found in some pockets (Fig. 176 left). Some cube penetration twins have also been found (Fig. 178). Most of the crystals are smaller than 1 cm.

Many very nice specimens have been produced from different pockets, sometimes as fluorite cubes perched on quartz crystals (Fig. 175). In a few pockets the rate of growth evidently was very rapid, producing crystals with stacked cubic faces (Fig. 177). Severe etching of the fluorite took place in some areas, leaving crystals with etched faces and edges.

Most of the fluorite from the mine fluoresces pale blue to blue-white. The fluorescence in some crystals is brightest along the color bands. This feature demonstrates the close relationship of color centers and fluorescence. Color centers in fluorite (Smakula 1950) are the result of an electron occupying one of the fluorine ion sites in the lattice, such centers being caused by imperfections during the growth of the crystal (Nassau 1978). Some of the samples also show phosphorescence. The zoned nature of the fluorescence and the phosphorescence is probably indicative of the presence of rare earth elements in the mineralizing solutions (Przibram 1935; Bill *et al.*, 1967). The source of these rare earth elements was probably the small pegmatites in the Precambrian granitic gneisses of the groundmass. The different colored fluorites present in the Sweet Home mine indicate two distinct periods of deposition over a decreasing temperature range (Reynolds, this issue). Fluorite from the Sweet Home mine is also discussed by Muntyan (1996).

Galena PbS

The prevailing view has been that galena has long been an important silver ore mineral in the Alma district (Patton, 1912), and that it is largely confined to deposits in calcareous rocks, whereas gold deposits occur in siliceous rocks. Others (Behre, 1932, 1953; Butler and Singewald, 1940; Singewald and Butler, 1941) note that argentiferous tetrahedrite, argentite and other minerals may account for most of the silver in the primary galena-bearing ores. Other reports on sulfide ore mineralogy include Corn (1957), Bloom (1965), Stevens (1965), and Machado (1967). Silver content of galena from the mine is discussed by Modreski (1988). Most recent data is in Honea (1992) and Wenrich and Aumente-Modreski (this issue).

Some small, well-formed, galena cubes, usually less than 1 cm, have been found in the Sweet Home mine and make attractive specimens. These are associated with other sulfides and quartz.

Goyazite $SrAl_3(PO_4)_2(OH)_5 \cdot H_2O$

Goyazite was first reported from the Sweet Home mine by Kosnar (1979b). One other identification is known, from a specimen found on the mine dump several years ago by Ray Randstrom (written communication, 1994). This elusive species has not been found in recent freshly mined material. Kosnar reports attractive, well-formed, brilliant orange goyazite crystals up to ¼ inch that are associated with pink to purple fluorite crystals, gemmy rhodochrosite, and pale-green fluorapatite crystals in vugs with sulfide and quartz matrix. Paul Hlava (written communication, 1994) confirmed the identification of the Ransom sample and indicated that in addition to an inner composition of goyzite, there was an outside growth of svanbergite (DMNH #16852).

Greenockite CdS

Greenockite was first discovered at the Sweet Home mine by Bryan Lees in 1994. A small pocket near the Blueberry Pocket in the GPR Drift contained 3-mm to 8-mm pyrite specimens that were coated with a grayish green coating approximately 2–3 microns thick. SEM analysis by Peter Modreski, in 1994, showed the coating to be greenockite.

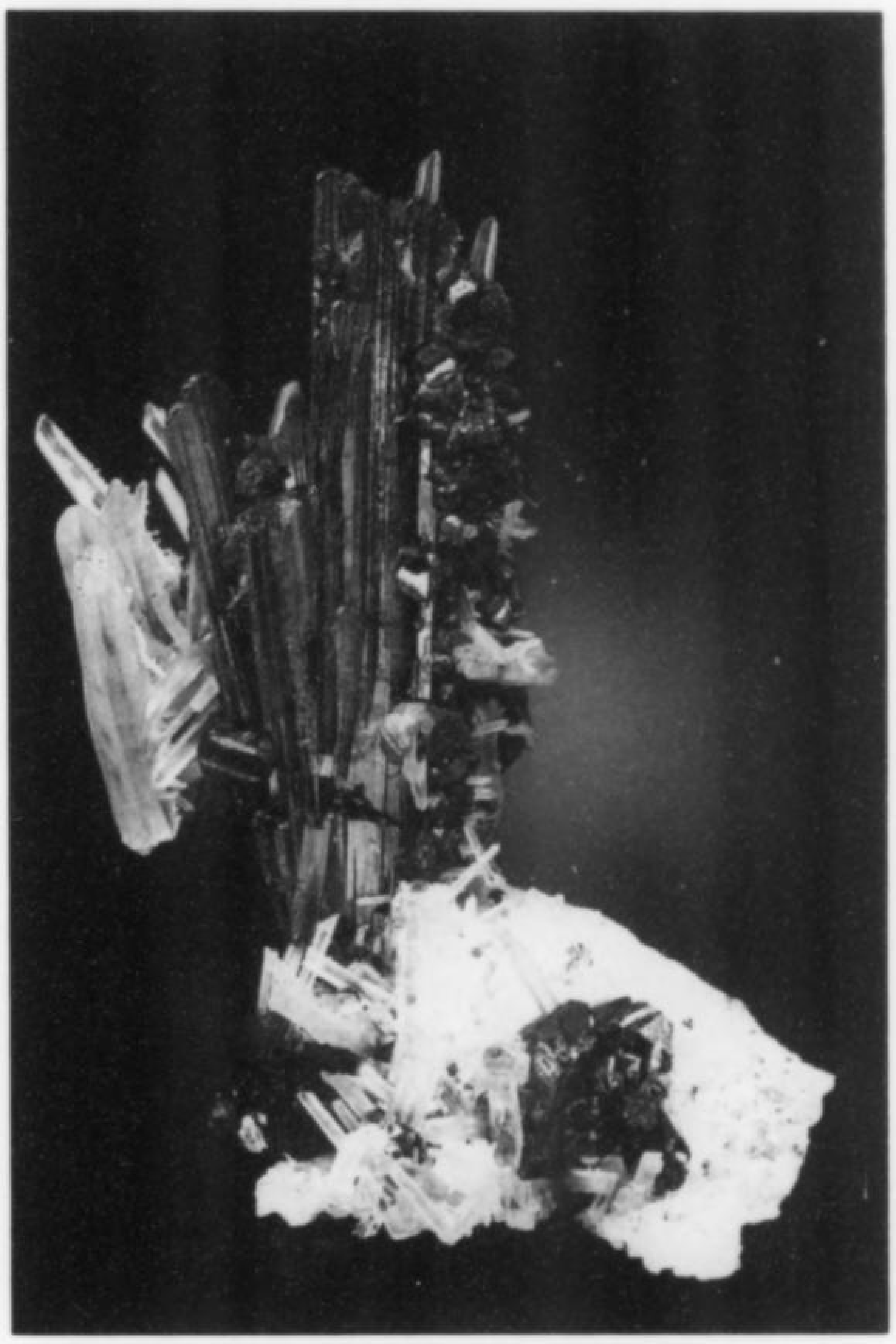


Figure 179. **Hübnerite blade with quartz and sphalerite; 5.4 cm high. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

Hübnerite $MnWO_4$

Hübnerite has long been known from the mine, so finding crystallized specimens was no surprise; in fact, many collectors and curators anticipated that fine material would be located when the mine opened in 1991. Hübnerite crystals were known to occur in the first drift to the northeast in the main adit by Belser (1956); he reported that 1,000 pounds of ore containing 10 percent WO_3 was shipped from the talus near the upper workings of the mine. Hübnerite is generally uncommon in the veins exposed between 1992 and 1995. When it is found, it mainly occurs as crystallized blades with needle quartz, associated with sulfides, rhodochrosite, and fluorite. Excellent specimens came from the Tetrahedrite Stope, Crosscut No. 3. Typically, a single blade of hübnerite up to 3-cm long, with a bright luster, is associated with needle quartz and other minerals. Some large specimens were encountered; one 28 x 20 x 9.5-cm mass of intergrown hübnerite crystals (DMNH #16812) came from the Tetrahedrite Stope.

Malachite $Cu_2(CO_3)(OH)$

Light green microcrystalline coatings on chalcopyrite crystals are most often malachite (Peter Modreski, personal communication, 1995); however, no detailed study has been done. Some green to blue-green coatings found on chalcopyrite may be some other mineral, for example, serpierite (E. E. Foord, written communication, 1995).

Muscovite $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Muscovite and sericite are pervasive gangue minerals in the Sweet Home mine. Unaltered muscovite, in well-formed crystals up to 8 mm, occurs with quartz and sulfides in parts of the mine, especially the Coors Pocket. Muscovite was analyzed on the microprobe (Wenrich and Aumente-Modreski, this issue). Fine-grained sericite is more common than euhedral muscovite and it is a constituent of the matrix in the veins. It also fills empty spaces in the crystal pockets, along with dickite. It is intimately associated with massive anglesite in Crosscut No. 2.

Mawsonite $Cu_6Fe_2SnS_8$

Mawsonite was reported in 1994 by Beda Hofmann, Bern Museum, Switzerland. It was confirmed by electron microprobe on material he collected at the mine in 1992. It is an intergrown constituent in the sulfide mineralization. This is the first report of a tin mineral from the Sweet Home mine.

Molybdenite MoS_2

Coarse, crystalline molybdenite occurs in small amounts with quartz in Sweet Home mine veins, but its occurrence has not been specifically studied. The mineral was noted by Corn (1957). Molybdenite is reported, with stains of ferrimolybdite, in the Watercourse Raise and from an adit 160 feet northwest of the present portal of the Sweet Home mine (Bryan Lees and Dean Misantoni, personal communication, 1994).

Pyrite FeS_2

Collectors are usually captivated by the Sweet Home mine pyrites with their distinctive growth habits, specifically the cubic crystals with saw-tooth edges (Fig. 180). Probably the first to record these pyrites was Roots (1951b), who described digging in a vein at the Sweet Home mine in search of rhodochrosite and finding "⅝ by ½-inch-sized cubes with beveled edges and corners." Crystallized specimens of pyrites were not well-known from the mine until 1993 when Bryan Lees opened up the "Pyrite Pocket" in the "Tetrahedrite Stope" on Crosscut No. 3. Most of the crystals are of particular interest because of their rounded, rather bulging, striated cubic faces and serrated edges. The details of these growth patterns are best seen under low magnification, where the step-like striations on the faces can be observed to intersect at the edges of the crystals creating the repetitious saw-tooth patterns. This texture is not limited to the edges but also selectively occurs on the crystal faces. Most of the crystals show octahedral modification on the corners. These pyrites form as attractive intergrown clusters of crystals on white quartz crystals directly associated with dark gray sphalerite. The cubes range from 5 mm to 2.5 cm across; the largest single cube observed from this pocket is 4.4 cm across (DMNH #16843). Not all crystals are distorted or have striations. One (DMNH #16841) is a nearly perfect 2-cm cube with mirror-like faces; the corners are also modified by the octahedron. Pale purple fluorite cubes and single blades of hübnerite occur on the quartz matrix with these pyrites.

***Figure 180.* Pyrite crystal with serrated edges, 1.6 cm. Denver Museum of Natural History collection; photo by Jack Thompson.**

Quartz SiO_2

Quartz is ubiquitous in the veins and is undoubtedly the major gangue mineral. However, in some veins, sericite is as abundant as or more abundant than quartz. The quartz may be massive within the veins but it usually forms as attractive white to transparent crystals less than an inch long in open spaces associated with pyrite, chalcopyrite, hübnerite, rhodochrosite and fluorite. All plates and hand-sized specimens from the Rainbow and Museum pockets have a myriad of freestanding and intergrown quartz prisms as the background for the other minerals.

Rhodochrosite $MnCO_3$

The Sweet Home mine has long been recognized as the source of the world's finest rhodochrosite, but it was not until 1992 that several of the most extraordinary crystals were unearthed. Early references to the mineral occurring at the mine include Endlich (1878), Emmons (1886), and Dana (1898). Smith (1993) indicates the mine was known in 1873 and perhaps earlier. It is surprising how little documentation exists on rhodochrosite discoveries; it can only be assumed that fine crystals were destroyed during early-day silver mining. One report by Caplan (1980) mentions that ". . . it was Pohndorf and Hart of Manitou, Colorado who bought the

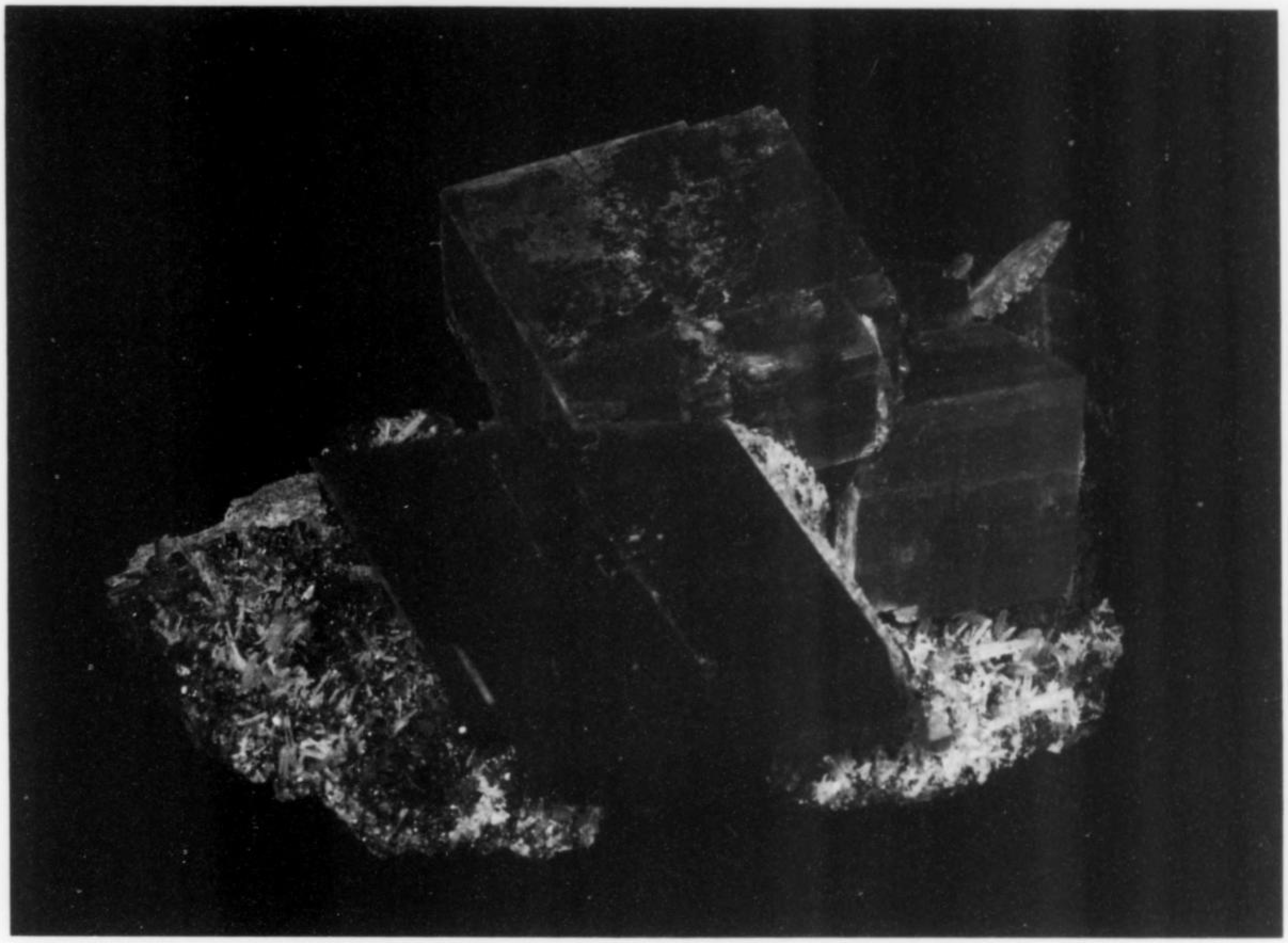


***Figure 181.* Rhodochrosite crystal group found in 1992, with crystals up to 7.6 cm. James Horner specimen; photo by Ken Erickson.**

entire 'original' pocket of Alma rhodochrosite. They divided the pocket, and everything was gone long before my time." White (1981) elaborated on this find and remembers seeing rhodochrosite crystals on exhibit in William C. Hart's *Rocky Mountain Gem Store* on Ruxton Avenue in Manitou Springs, Colorado. Arthur G. Pohndorf owned a Denver jewelry store for many years before World War II and sold a variety of minerals, including Sweet Home mine rhodochrosites.

After World War II individual collectors poked around at the Sweet Home mine (Roots, 1951a,b; Ingle, 1958; and Miller, 1971), but it was not until the 1960's that superb crystals were mined and came to be widely known. Peter Bancroft (1973, 1984) did much to promote Sweet Home mine rhodochrosite to the public—first (1973), by using a color photograph of the "Alma Queen" on the cover of his book *The World's Finest Minerals and Crystals*, and second (1984), by recording the known history of the locality and the discovery of remarkable crystals in 1964 by Ed McDole and Warren Good. The rhodochrosite crystal known as the Alma Queen was collected in that era; it resides today in the Houston Museum of Natural Science. Another exceptional specimen dating from that time consists of two intergrown, 4-inch, translucent crystals at the Denver Museum of Natural History; a photograph of the specimen is shown in Kosnar (1979b, fig. 6) and Gressman (1988). Additional information about discoveries in the 1960's may be found in Frazier and Frazier (1996).

It was not until the summer of 1992 that unprecedented single rhodochrosite crystals and groups of intergrown crystals on matrix were again found. Progress at the mine by Bryan Lees during this time was recorded by Bode and Klaus (1992), Cook (1993), Kile and Lees (1993a,b), and Lees (1994).

Undoubtedly the finest and most publicized specimen is the "Alma King," an unprecedented, deep red, single 5½ x 6½-inch rhombohedron that was found in a vug named the "Rainbow Pocket" in the Tetrahedrite Drift on the second crosscut (Fig. 44). This crystal and a 1½-inch companion rhombohedron, are on a matrix plate that measures 23 by 17 inches. It is associated with tetrahedrite, and a concentration of small purple fluorite crystals, along with a small blade of hübnerite. This discovery and another large slab (Fig. 45), with a clustering of five large rhombohedra, is described and illustrated by Moore (1993). The Alma King, described by Murphy (1994) and Voynick (1994b), is on permanent display at the Denver Museum of Natural History.

Gem-clear rhodochrosite crystals are rare but have been found. Up until the mine was reopened in 1992, gem-quality material was very rare. Today, transparent cleavage pieces have yielded handsome faceted gems; the largest known, on exhibit at the Denver Museum of Natural History, weighs 65 carats.

Sphalerite (Zn,Fe)S

Sphalerite is one of the most abundant species found in the Sweet Home mine. It is an important massive component in the ore, and commonly also occurs in crystal pockets as small, well-formed black, green, yellow or red crystals associated with other sulfides and euhedral fluorites and rhodochrosite.

Spionkopite $Cu_{39}S_{28}$

Spionkopite is one of the few minerals to be newly identified since the mine was reopened in 1991 (Wenrich and Aumente-Modreski, this issue). It was found during electron microprobe analysis, associated with bornite, digenite, stromeyerite, and possibly jalpaite.

Svanbergite (see goyazite)

Tetrahedrite/Tennantite $(Cu,Fe,Ag,Zn)_{12}(SbAs)_4S_{13}$

Crystals of tetrahedrite/tennantite from Buckskin Gulch were listed by Endlich (1878) but no further details are reported. Argentiferous tetrahedrite and freibergite were considered among the most important ore minerals responsible for most of the silver in the silver-lead deposits of the Alma district (Singewald and Butler, 1931, 1941; Behre, 1953). Modreski (1988) analyzed selected Sweet Home mine specimens with the "KEVEX" energy-dispersive, X-ray fluorescence spectrometer, and calculated relative percentages of elements contained in the samples. He found that material labeled "freibergite" (DMNH #12467) had only about 1 weight % Ag and is stoichiometrically tennantite. Modreski indicated that "freibergite" should more appropriately be referred to as tetrahedrite/tennantite. See also Wenrich and Aumente-Modreski (this issue) for quantitative electron microprobe analysis of these minerals, and also Raabe and Sack (1984).

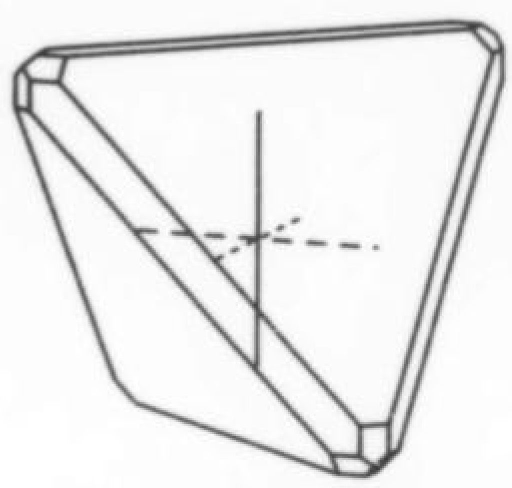


Figure 182. **Tetrahedrite crystal drawing showing habit typical of the Sweet Home mine.**

Excellent tetrahedrite/tennantite specimens are recognized from the Sweet Home mine. Specimens are attractive, with single euhedral crystals or as intergrown clusters of crystals on sulfide matrix, associated with euhedral rhodochrosite, quartz, fluorite, sphalerite and hübnerite. Typically the crystal surfaces are bright and untarnished, often with a distinctive specular appearance. Crystals are generally ¼ to 1 inch in size, but individual tetrahedrite/tennantite crystals up to 2 inches are known, and fragments of even larger crystals have been seen.

Topaz $Al_2(OH,F)(SiO_4)$

Topaz was reported by Kosnar (1979a) as part of the pegmatite assemblage in the host rock at the Sweet Home mine. One very small topaz crystal in a matrix of quartz has been found in the present mining operation. It is assumed that this mineral is more prevalent because of the abundance of topaz inclusions (<0.01–40 µm long) in quartz crystals associated with the sulfide minerals, tetrahedrite, rhodochrosite, and fluorite (Reynolds; Wenrich and Aumente-Modreski, this issue).

Triplite $(Mn,Fe,Mg,Ca)_2(PO_4)$

This rare phosphate was discovered while examining inclusions in rhodochrosite, and was subsequently verified by electron microprobe analysis (Karen Wenrich, personal communication, 1996). The triplite occurs as solid inclusions in fluorapatite, which itself is an inclusion in rhodochrosite.

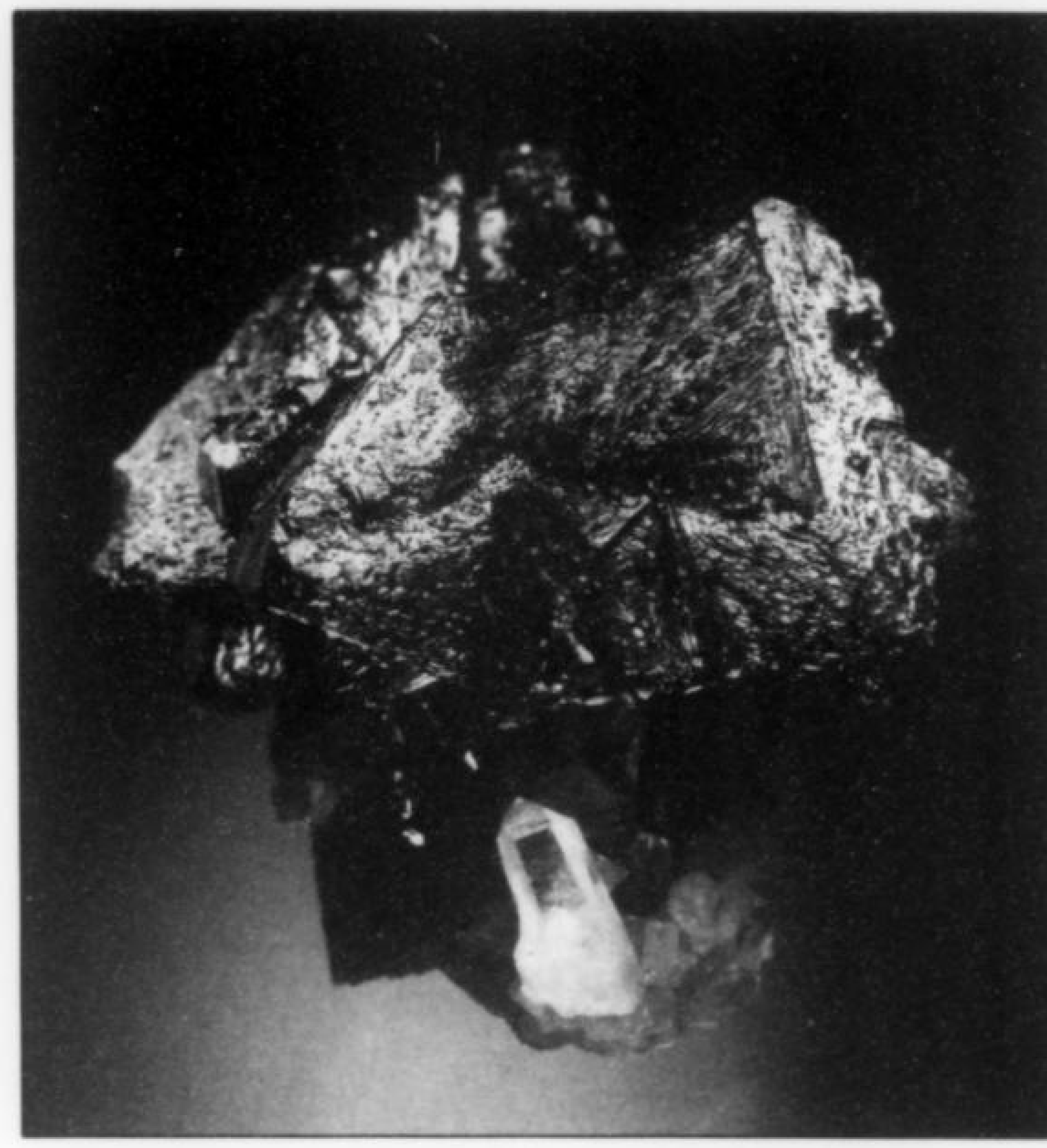


Figure 183. **Tetrahedrite crystals with rhodochrosite, 1.5 x 2.0 cm. Sweet Home Rhodo, Inc. specimen; photo by Jeff Scovil.**

Unknown sulfosalt

Tiny, 1–2 mm, black, striated, prismatic crystals intimately associated with needle quartz and sphalerite were found on material collected in Crosscut No. 3. Only two microcrystals are known, not enough for a thorough analysis. One crystal was studied by Peter J. Modreski and provisionally believed to be eclarite ($Pb_9(Cu,Fe)Bi_{12}S_{28}$), or possibly another orthorhombic lead-copper-iron bismuth sulfosalt, miharaite ($PbCu_4FeBiS_6$).

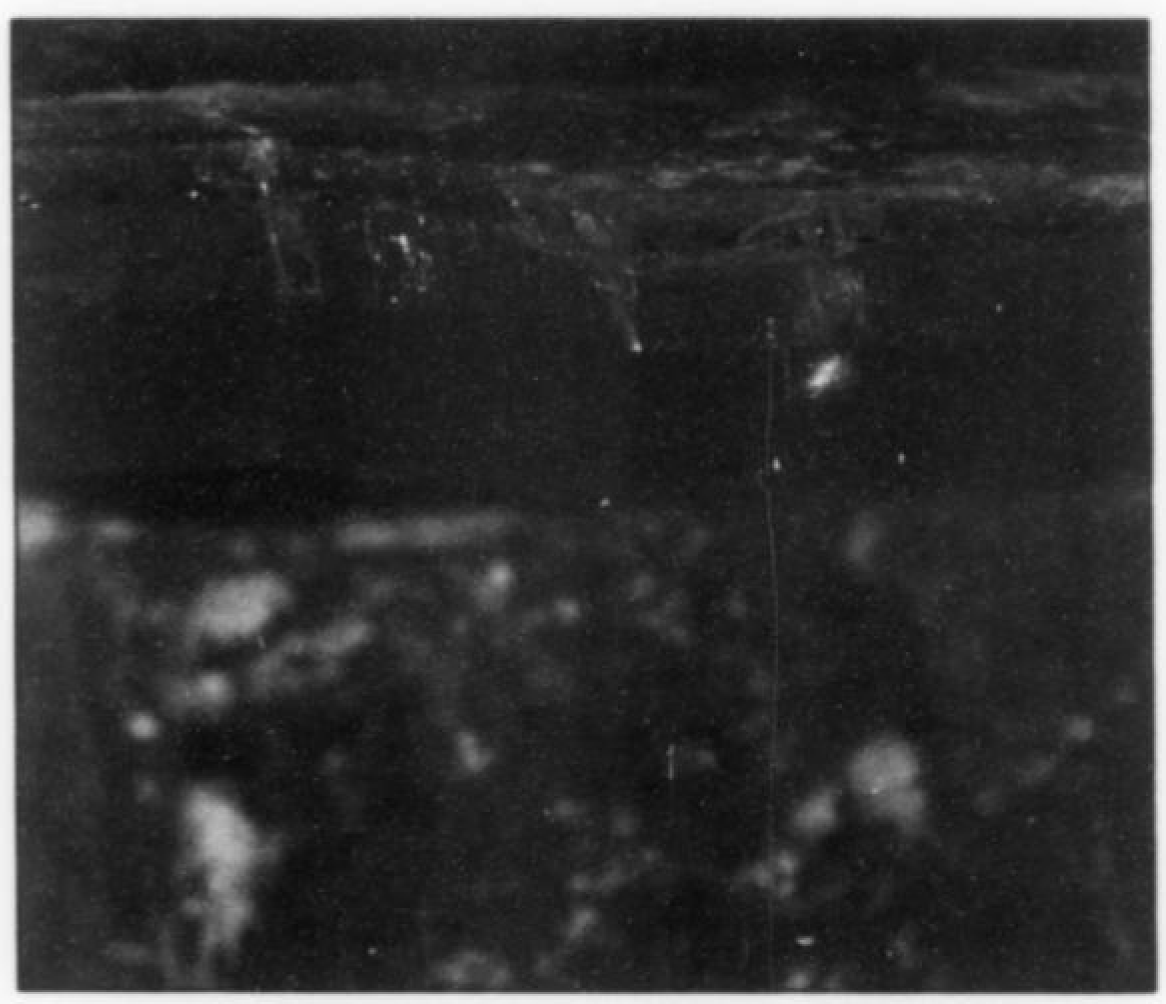


Figure 184. **Rhodochrosite sample from the Rainbow Pocket showing the pale pink rim coating the underlying gemmy cherry-colored rhodochrosite. The corner of the light pink rim is chipped, exposing the underlying cherry rhodochrosite. The gemmy rhodochrosite and the lighter-colored, lower-quality rim are intergrown with sulfides, particularly sphalerite.**

SWEET HOME RHODOCHROSITE—WHAT MAKES IT SO CHERRY RED?

Karen J. Wenrich
Wenrich Petrography * Mineralogy * Geochemistry
P.O. Box 5054
Golden, Colorado 80401

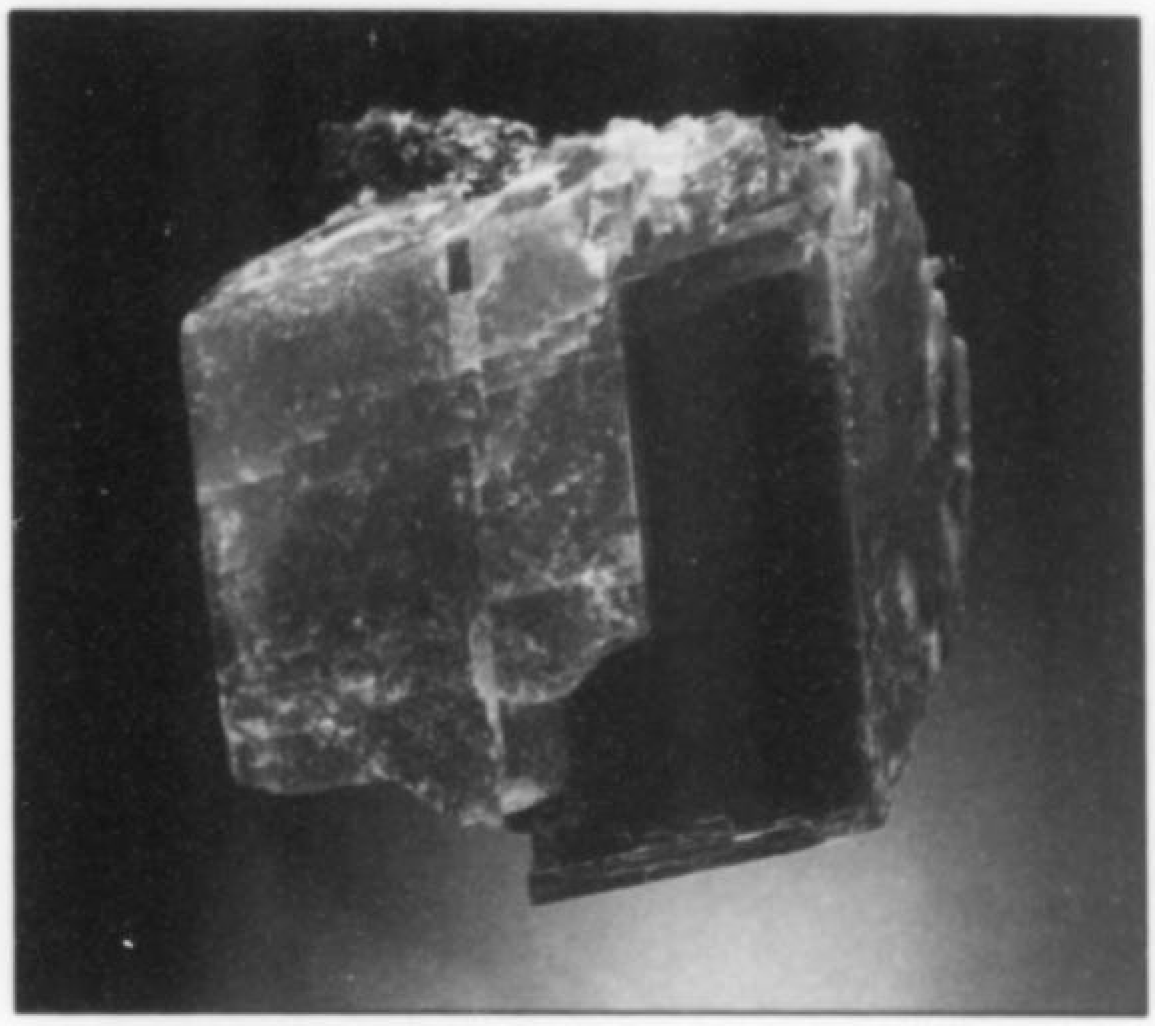


Figure 185. **The entire 1-inch specimen (see Fig. 184) showing pale and dark areas. The gemmy rhodochrosite in the center of the specimen formed earlier at a higher temperature and is essentially pure $MnCO_3$, whereas the later, lower-temperature, lighter pink rhodochrosite contains several percent Ca+Mg+Fe in substitution for Mn in the rhodochrosite structure. Sweet Home Rhodo, Inc. collection.**

Over the past 100 years the Sweet Home mine has produced rhodochrosite of extraordinary beauty; it is unrivaled in its striking color relative to rhodochrosite from any other locality in the world. Several articles have been written describing its color: "Sweet red rhodochrosite" (Jones, 1994), "Rhodochrosite: hot, pink, & pretty" (Jones, 1986). Unfortunately, not all rhodochrosite that comes from the Sweet Home mine is as red and gemmy as those in the Good Luck Pocket and Watercourse Drift. Why not? Because a rind of paler pink rhodochrosite coats the gorgeous cherry-red interior of many specimens from the Sweet Home mine (Figs. 184, 185). This lighter pink rim that coats and invades the cherry rhodochrosite along fractures is firmly attached. What process created the pink rim and why is it different from the cherry rhodochrosite?

The geoscience literature currently lists over 400 articles describing rhodochrosite and its occurrences throughout the world. However, little is available on the chemistry of rhodochrosite at these worldwide locations. Sweet Home Rhodo, Inc. decided that a research effort into the local geology and chemistry of the rhodochrosite and associated sulfides might result in the development of exploration technology providing clues for more successful rhodochrosite mining. The mining company wanted tc develop a technique that would allow them to concentrate on areas with gemmy cherry rhodochrosite and avoid areas that produced pink opaque rhodochrosite.

WORLDWIDE RHODOCHROSITE LOCALITIES

Rhodochrosite commonly occurs as a gangue mineral in mines throughout the world. However, it rarely occurs in a gemmy, lustrous red form like that from the Sweet Home mine in the Mosquito Range. Furthermore, only Leadville and Climax in the Mosquito Range have produced some rhodochrosite. A comprehensive description of worldwide occurrences is beyond the scope of this article, but a few localities with material comparable to that of the Sweet Home mine are of particular interest.

The N'Chwaning mine, in the Kalahari Manganese Field of the Black Rock district, Northern Cape Province, South Africa, has long been known to collectors as a producer of exceptional rhodochrosite specimens. The Kalahari district began production in the 1940's and continues to operate today. However, fine rhodochrosite specimens have not been produced from this mine for many years. Rhodochrosite from this locale occurs as groups of gemmy, intense red scalenohedrons on a black manganese matrix. They are typically lustrous and very transparent. The genesis of this mineralization is very different from that of the Sweet Home mine. The ore from this mine has been hydrothermally altered and metamorphosed, which produces a very high manganese content (Cairncross and Dixon, 1995).

Other fine rhodochrosites have been produced from the sulfide ore deposits of Peru, specifically, from the Pasto Bueno mine. Rhodochrosite from this locality is rhombohedral in habit, lustrous and very gemmy. It formed in a mineralizing environment similar to that at the Sweet Home mine. Here, ores have been hydrothermally emplaced but have not been metamorphosed. The specimens are reminiscent of Sweet Home material. Rhombohedrons are perched on clear quartz crystals, commonly in association with fluorite.

Another locality of mention for rhodochrosite is the Catamarca deposit in Argentina. The rhodochrosite from this locale is famous for its stalactitic form. Single and multiple stalactites have grown up to 2 feet in length. The formation of this material is quite different from either N'Chwaning, Pasto Bueno, or Sweet Home. Here the material is deposited in layers similar to helectitic cave growth. Round slices cut and polished from this material have been made into beautiful jewelry and *objets d'art*, many showing interesting concentric bands. The material is sufficiently massive that most rhodochrosite beads sold throughout the world have been cut from Catamarca rhodochrosite. Most of the material is of a rich pink, opaque variety. However, a small percentage of the material is near-gem red.

A few more minor localities of note include Butte, Montana; the Oppu mine, Aomori Prefecture, Japan; and the mines of the Santa Eulalia district, near Chihuahua, Mexico. The Butte rhodochrosites form simple, relatively small, rhombohedral crystals with a dusting of pyrite. The Japanese rhodochrosites form bright pink botryoidal coatings on matrix. Santa Eulalia has produced bright pinkish red rhodochrosite scalenohedrons.

Finally, it should be mentioned that besides the Sweet Home mine, Colorado contains four other localities which have produced high-quality rhodochrosite. They are: Climax, Silverton, Bonanza, and Central City. Of these, the Climax mine has produced material closest in quality to the Sweet Home mine. Perhaps this is because it shares Sweet Home's interesting depositional environment, being only 5 miles away.

SWEET HOME RESEARCH

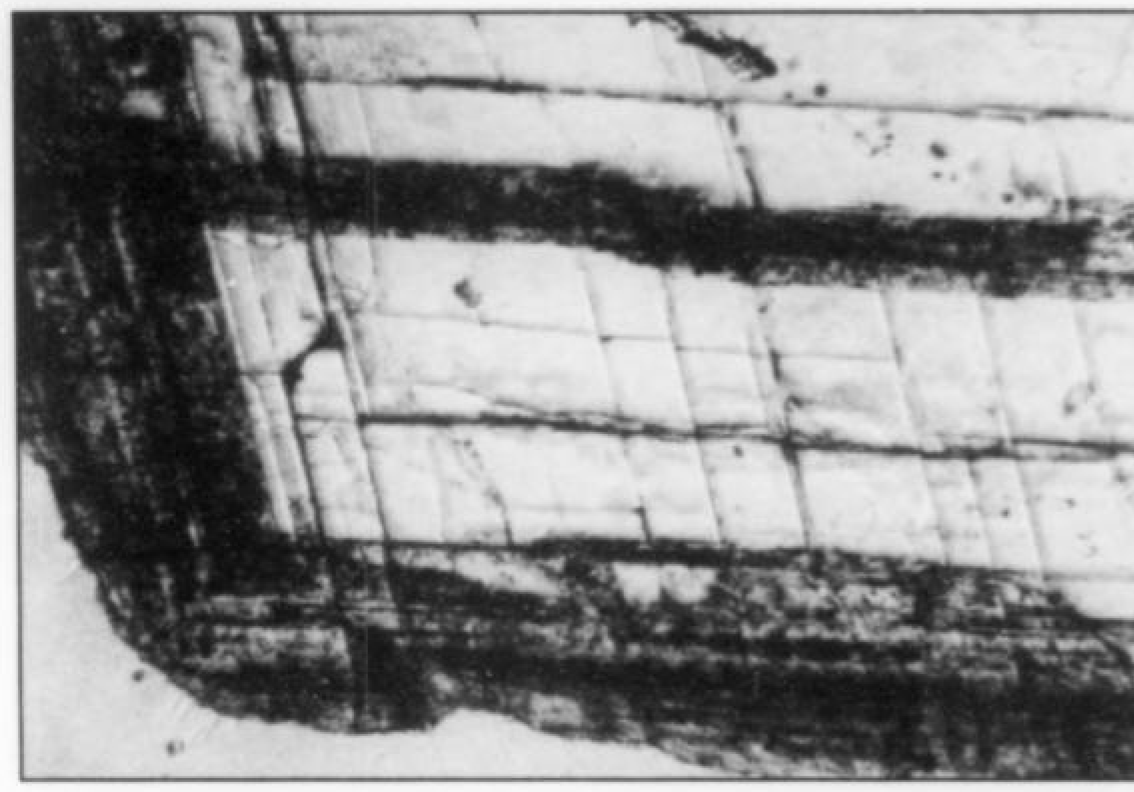
Atomic absorption analyses run on bulk rhodochrosite prior to 1993 by David Helt of Golden Technical Systems indicated the presence of several hundred ppm Zn, Ca, and Mg and several thousand ppm Fe. These data raised the question of whether the anomalous zinc was substituting in the rhodochrosite crystal structure or was present merely as a contaminant, prompting the current study.

Specimens from the same location were studied by K. J. Wenrich using the scanning electron microscope (SEM). The SEM results suggest that much of the Zn and most of the Fe in the atomic absorption analyses are due to very fine inclusions of sphalerite and pyrite along the rhodochrosite cleavage planes (sulfur content increases directly with Zn and Fe contents). It was then decided that quantitative spot analyses of the rhodochrosite and associated sulfides were necessary.

Polished sections were prepared from 20 samples, each of which was studied petrographically for phases suitable for fluid inclusion (see Reynolds, this issue) and quantitative electron microprobe analyses. The samples came from 12 separate stopes and drifts within the mine. Quantitative analyses were performed on a JEOL electron microprobe operated at 15KV and 20 nanoamps of beam current with a spot size of <1 μm (further details can be obtained from the author). Analyses of 127 rhodochrosites (for 28 elements each) representing 13 pockets in the Sweet Home mine were completed. The intrinsic value of microprobe analyses to the mineralogist lies in the ability of the instrument to produce quantitative chemical analyses of spots that are as small as 2 microns. With the more sophisticated modern instrumentation now available, such as the new electron microprobes, it is possible to determine oxygen and carbon directly rather than by calculation. Table 7 shows 14 of the 28 elements for 15 representative samples of the 127 rhodochrosites from the Sweet Home mine. The remaining 14 elements determined show little variance between samples and are present in such low concentrations that they are not listed in the table; they are summarized in the table caption.

RESULTS

The pink rim around the cherry core is as striking petrographically in transmitted light as it is in hand specimen. Although neither the pink or cherry color can be readily observed in normal thin section because of the thin (0.03 mm) nature of the rock slice, the cherry core is transparent whereas the pink rim is dark and cloudy. This cloudy nature is due to numerous fluid and solid inclusions; inclusions are also present in the cherry rhodochrosite,



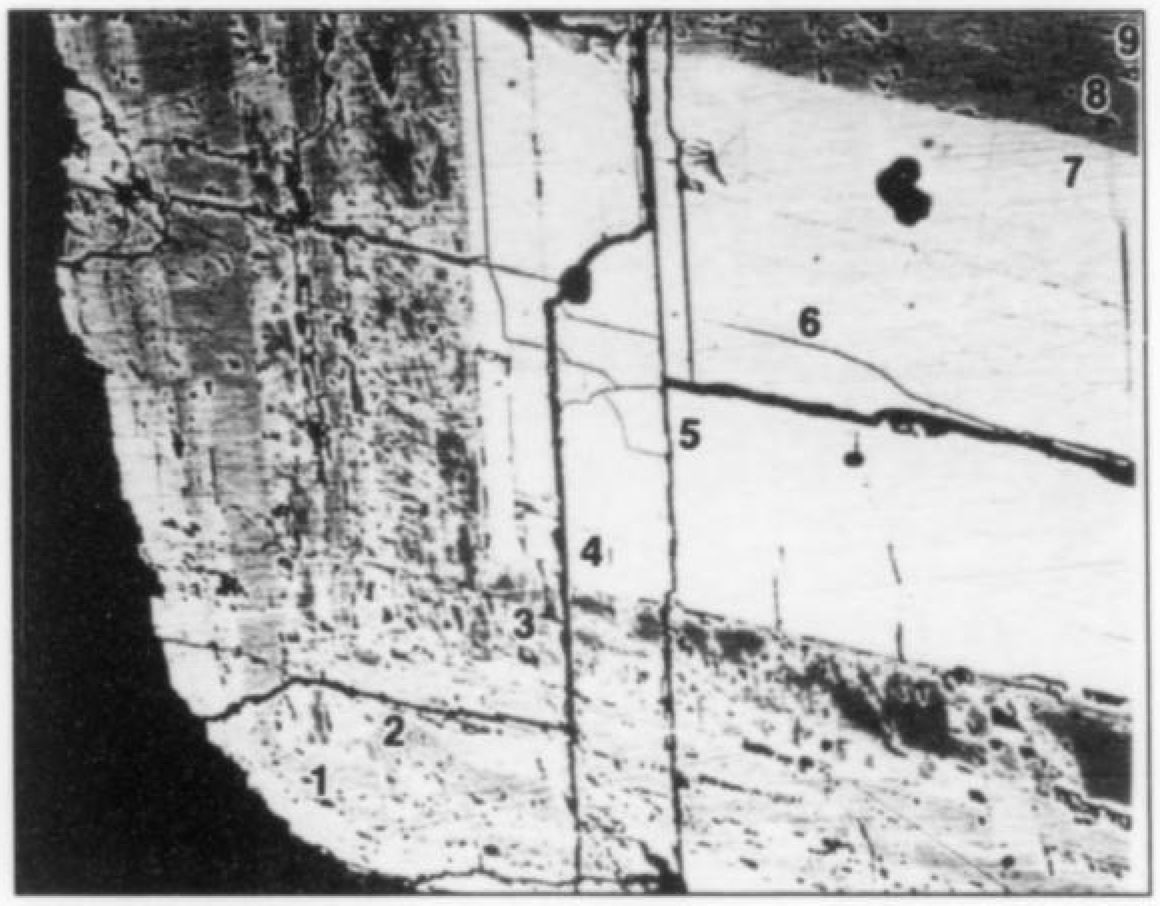


Figure 186. **Cherry rhodochrosite is transparent in thin section whereas the lower-quality pink rhodochrosite forms rims and fills fractures that are dark and cloudy. Sample 1-C-L95 (Area A) from the Rainbow Pocket. *(Top)* Plane transmitted light. Horizontal field of view is 700 μm. *(Bottom)* Electron backscatter image; horizontal field of view is 250 μm. A traverse of spot chemical analyses was made across this sample, providing an excellent demonstration of the substantial variation in Fe, Ca, and Mg content between the cherry and pink rhodochrosite. The spots are recorded by number on the photograph and correspond to the sample numbers in the following table of Fe, Ca, and Mg contents in weight percent:**

	1	2	3	4	5	6	7	8	9
Fe	8.8	8.6	9.2	1.2	1.2	1.3	1.3	9.1	9.0
Ca	0.7	0.6	0.7	0.1	0.1	0.1	0.1	1.1	1.1
Mg	0.6	0.6	0.7	0.1	0.1	0.1	0.1	0.8	0.8

but are sparse. Both topaz and apatite occur as solid inclusions in the rhodochrosite. The lower-quality rhodochrosite fills fractures in the cherry rhodochrosite, as well as forming rinds around many crystals, demonstrating that it is clearly later than the cherry rhodochrosite (Fig. 186 top). This indicates that rhodochrosite in the Sweet Home mine formed in two distinctly different stages of mineralization.

Electron microprobe analyses reveal that the two distinctly different colors of rhodochrosite have distinctly different composi-

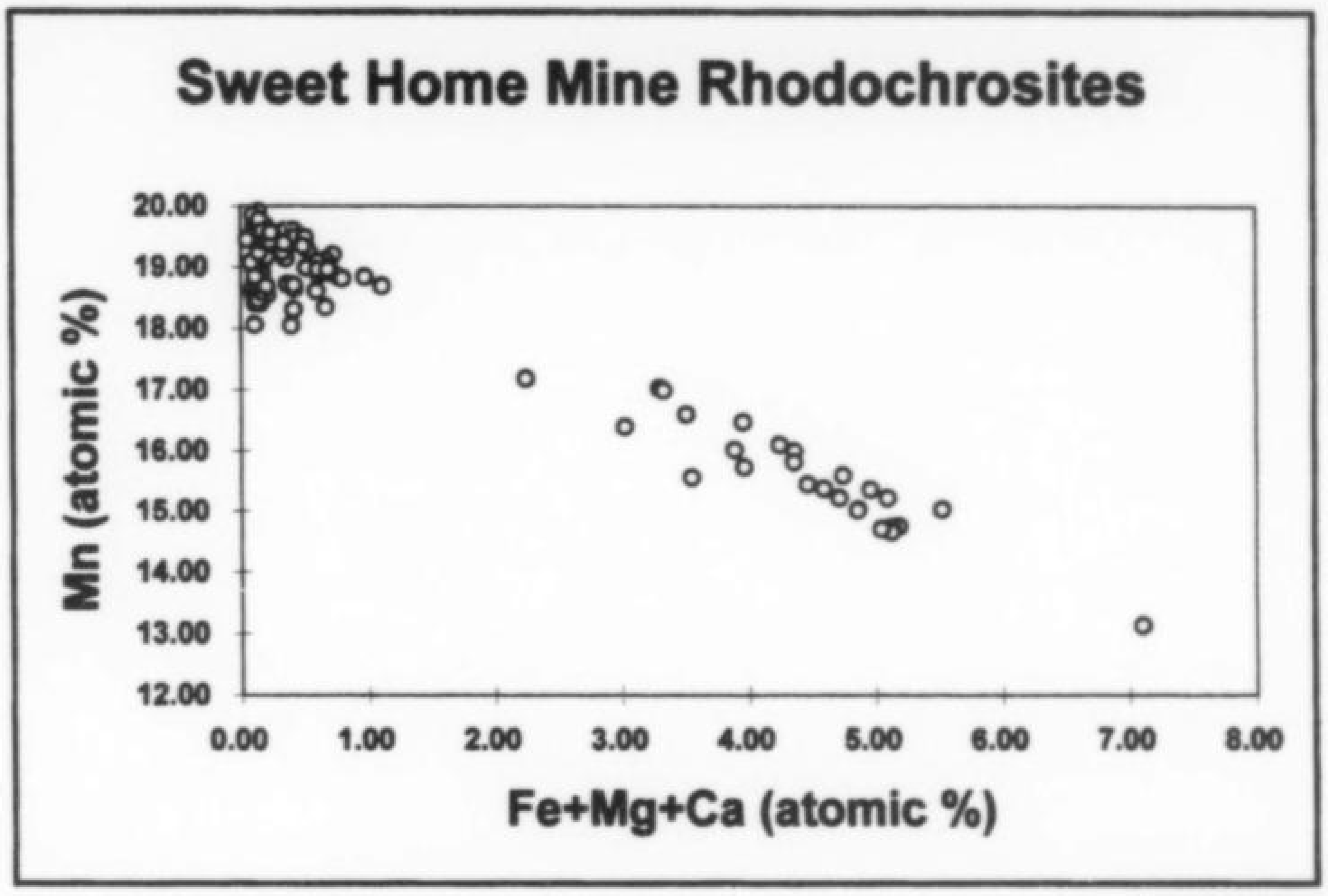
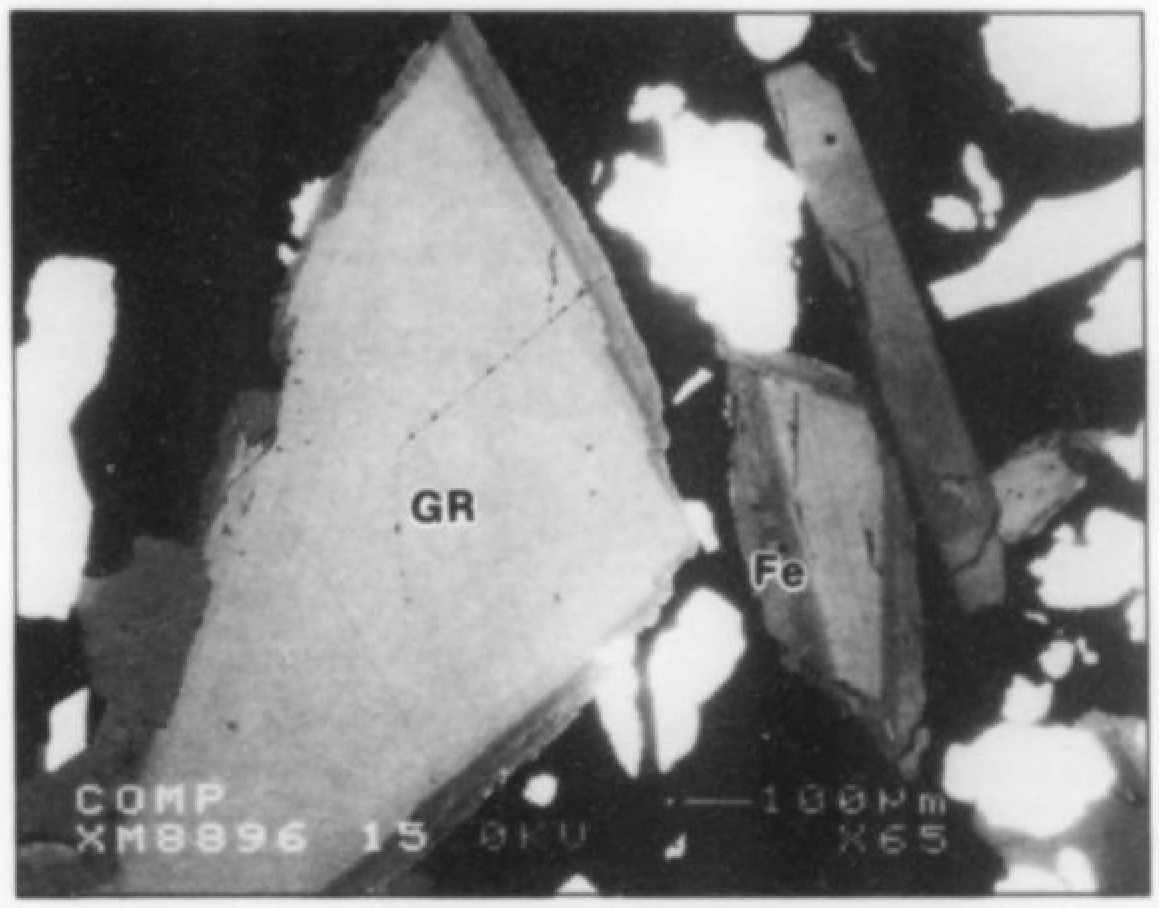
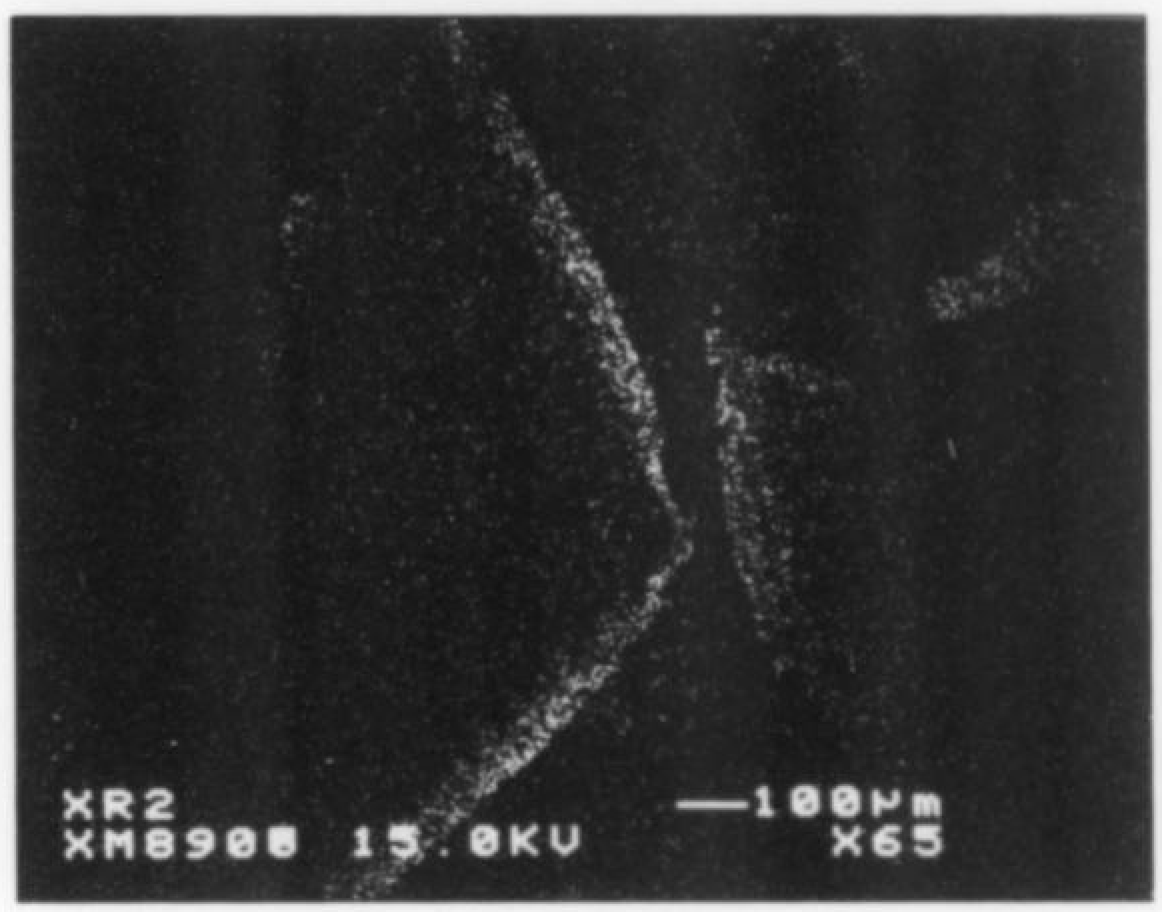


Figure 187. **Summary of 127 electron microprobe results showing Mn versus Mg+Fe+Ca in atomic percent. There is a distinct break in composition between the two stages of rhodochrosite. The gemmy, cherry rhodochrosite consistently has Mg+Fe+Ca contents that are <1% whereas the lower-quality pink rhodochrosite has totals of Mg+Fe+Ca that are >2% and as high as 7%.**

Figure 188. (Top) **Electron backscatter image of gemmy rhodochrosite (GR) with a Fe+Mg+Ca (Fe) rim; bright grains surrounding the rhodochrosite are sulfides. *(Bottom)* X-ray map of Fe. Bright spots represent areas of Fe concentrations. Sample F1-2 from the Empty Pocket in the Tetrahedrite Stope.**





tions. An electron backscatter image (Fig. 186 bottom) and element map of Fe for the same sample shown (Fig. 186 top) illustrate the results remarkably well. This image shows a traverse of spots that records each position of analysis. The traverse data demonstrate the substantial variation in Fe, Ca, and Mg content between the cherry and pink rhodochrosite. Spot numbers on the photograph correspond to analysis numbers in the small table of Fe, Ca, and Mg contents shown in the figure caption. Pink material contains as much as 7% (atomic) Fe+Mg+Ca replacing Mn in the rhodochrosite structure, whereas the cherry-colored, gemmy material is consistently less than 1% total Fe+Mg+Ca. Figure 187 summarizes the cation variation in the 127 rhodochrosite analyses. Figure 188 (top) shows an electron backscatter image of gemmy rhodochrosite with the Fe+Mg+Ca-rich rim; bright grains surrounding the rhodochrosite are sulfides (pyrite, chalcopyrite and galena). Figure 188 (bottom) is an X-ray map showing the increased concentration of Fe in the rhodochrosite rim. Maps of Mg and Ca show similar distributions. Iron contributes most of the contamination, with Mg second out of the 3 elements (Table 7). Figure 189 is a ternary diagram showing the total deviation from pure rhodochrosite (100% Mn) that Fe and Mg cause in rhodochrosites from various pockets in the Sweet Home mine. Analyses from different spots only a millimeter away within the same crystal show very different results, such as within rhodochrosite from the Tetrahedrite vein. The analyses from this vein that join the cluster of points at the top of Figure 189 are from gemmy red areas in the crystal, whereas those that have high Fe (near the central bottom of the diagram) are from a more opaque, pink-colored rim. Those pockets showing the greatest deviation from pure $MnCO_3$ are the Tight Pocket, Rainbow Pocket, Empty Pocket, and Red and Blue Pocket. Several of the pockets, including the Good Luck, have minor cracks in gemmy rhodochrosite filled with low-quality rhodochrosite. However, in the case of the Good Luck pocket the major contaminant is Mg, not Fe, and the high quality of the Good Luck pocket rhodochrosites testifies to the fact that a small increase in Mg, as shown in Figure 189, does not produce ugly rhodochrosites. In contrast, though, high Fe does. Although both Ca and Mg increase in some rhodochrosites, their increase is usually on the order of 3 times. However, Fe increases not uncommonly 30 times, and the rim on one sample shows a 400 times increase over the core.

Fluid inclusion temperatures determined by T. J. Reynolds (this issue) indicate that the early cherry stage of rhodochrosite formed at about 325°C whereas the later, lower-quality pink stage formed at temperatures less than 200°C. These fluid inclusion results in combination with the electron microprobe results provide answers to the question of what causes the difference between the two colors of rhodochrosite. The cherry-colored rhodochrosites were deposited early from moderately high temperature Mn-rich fluids that were very different from the late, low-temperature, Mn+Fe+Ca+Mg-rich fluids that deposited the pink rhodochrosites.

This substitution of Mg+Fe+Ca for Mn in the rhodochrosite

Table 7. **Electron microprobe chemical analyses of Sweet Home mine rhodochrosite.**

Oxygen and carbon were determined as unknowns and are reported as such, rather than calculated as oxides of the metals and CO_2, as was done in the past when analytical equipment did not provide the sensitivity. Each analysis determined 27 elements on a spot <1µm in size on a rhodochrosite crystal. Fourteen of the most concentrated elements are reported in this table; the values are in percent. The other elements, listed with their greatest concentration in Sweet Home rhodochrosite shown in parentheses, are Al (0.03), Cd (<0.01), Co (0.05), F (<0.05), K (0.03), Mo (0.06), Ni (0.04), P (<0.01), S (0.03), Se (0.03), Si (<0.01), Ti (0.03), V (0.04), and W (0.25). Sample numbers correspond to the following locations within the mine: *Rain* = Rainbow Pocket; *Good* = Good Luck Pocket; *Corner* = Corner Pocket; *Coors* = Coors Pocket; *Empty* = Empty Pocket; *Cash* = Cash Flow Pocket; *Tight* = Tight Pocket.

		Mn	*Fe*	*Mg*	*Ca*	*Zn*	*Cu*	*Ba*	*Ag*	*As*	*Sb*	*Pb*	*C*	*O*	*Total*
Pure $MnCO_3$		47.8	—	—	—	—	—	—	—	—	—	—	10.4	41.7	100.0
Rain	l-B-L95 spot T2	46.5	0.27	0.15	0.05	<.01	0.01	<.01	<.01	<.01	0.14	0.01	10.0	43.5	100.8
Rain	1-C-L95 spot A1 rim	36.7	8.77	0.58	0.74	0.06	<.01	0.07	0.02	0.01	<.01	<.01	12.4	42.6	102.0
Rain	l-C-L95 spot B5	46.5	0.19	0.15	0.04	<.01	<.01	<.01	0.04	0.01	0.06	<.01	12.2	41.2	100.6
Rain	1-C-L95 spot A21 rim	46.1	0.42	0.07	0.03	0.05	<.01	<.01	0.01	<.01	0.02	<.01	11.8	40.8	99.5
Good	2-B-L94 spot Al	47.3	0.14	0.05	0.03	0.07	0.01	<.01	0.02	0.01	<.01	<.01	10.7	42.8	101.2
Corner	4-B-L94 spot X21	46.8	0.14	0.04	0.02	0.02	<.01	<.01	<.01	<.01	0.03	0.10	10.1	40.3	97.7
Corner	4-B-L94 spot X23 edge	46.9	0.15	0.04	0.02	0.05	<.01	0.02	<.01	0.02	0.04	0.02	10.5	40.7	98.5
Coors	5-A-L94 spot X2	46.5	0.22	0.06	0.04	0.01	0.03	0.02	0.10	<.01	0.01	<.01	11.4	42.4	100.9
Coors	5-A-L94 spot X9	45.3	0.55	0.35	0.08	<.01	0.01	0.03	0.03	<.01	<.01	0.03	11.4	42.1	100.0
Empty	9-A-L94 spot A4 rim	38.8	5.58	0.65	0.15	0.05	<.01	<.01	<.01	0.01	<.01	<.01	—	—	—
Empty	9-A-L94 spot A14	46.1	0.15	0.07	0.08	0.03	<.01	0.05	<.01	<.01	<.01	<.01	—	—	—
Cash	11-A-L95 spot T1 edge	47.1	0.19	0.03	0.02	0.03	0.01	0.01	0.04	<.01	<.01	<.01	10.0	42.4	99.9
Cash	11-A-L95 spot T3	47.2	0.22	0.04	0.02	<.01	<.01	<.01	0.04	0.04	<.01	<.01	10.3	42.4	100.3
Tight	12-A-L95 spot A4 rim	39.7	3.75	1.51	0.94	0.06	<.01	0.01	0.01	0.02	<.01	0.04	10.5	42.1	98.7
Tight	12-A-L95 spot A8	46.4	0.17	0.09	0.08	0.02	0.01	0.02	0.05	<.01	0.01	<.01	10.4	42.6	99.9
Tight	12-A-L95 spot A 13	46.2	0.31	0.06	0.06	0.02	0.01	0.03	0.01	<.01	0.02	0.02	10.7	41.6	99.4
Tight	12-A-L95 spot Xl rim	38.3	2.60	2.63	1.41	0.01	<.01	<.01	0.03	0.07	0.05	0.03	12.5	10.7	98.3
Empty	FI-2 spot X7 rim	44.5	0.73	0.74	0.18	0.01	<.01	0.03	0.07	<.01	0.09	0.01	10.8	42.2	99.4

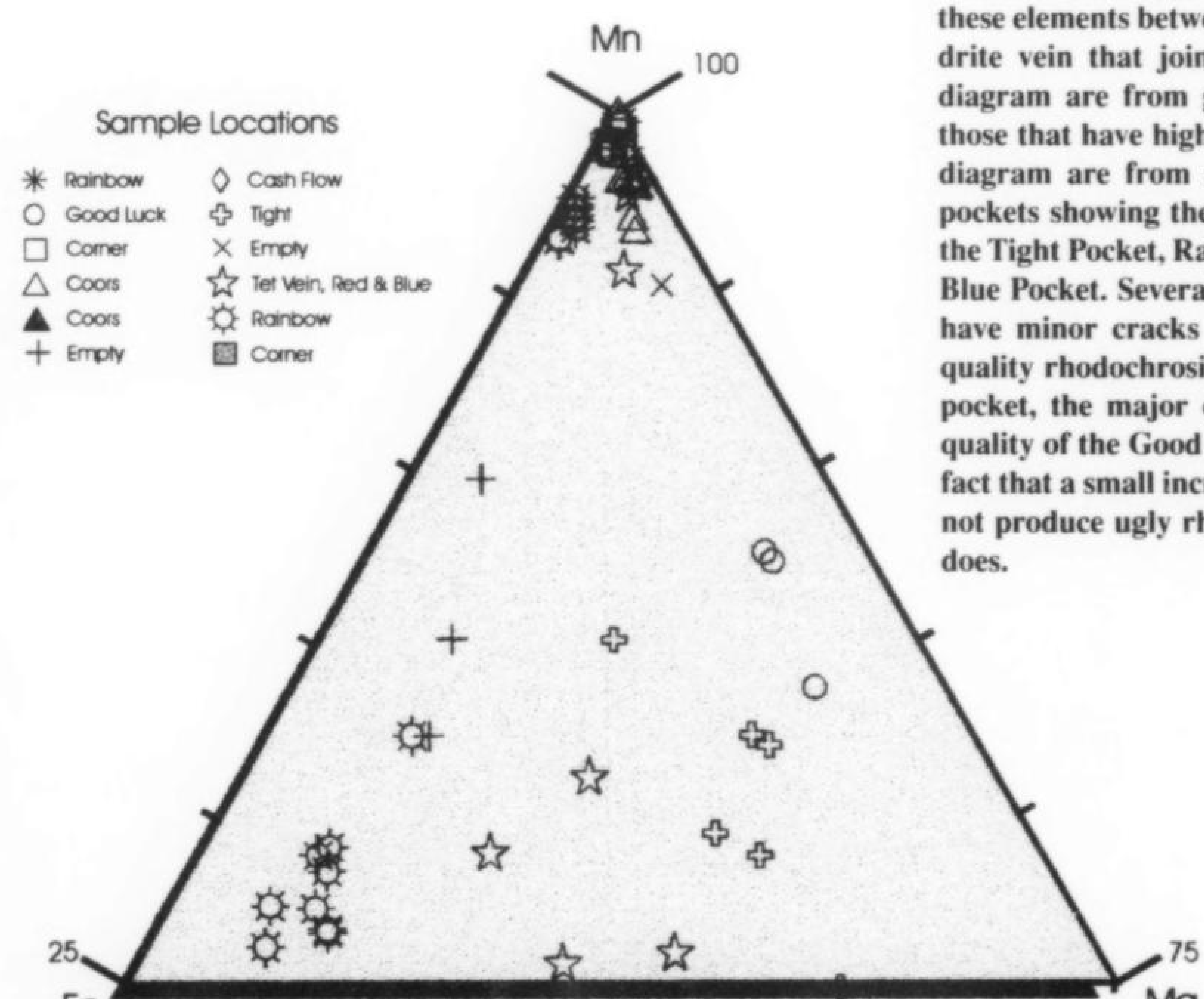


Figure 189. **Triangular diagram based on the atomic percent of Mn, Fe, and Mg, showing the variation in concentration of these elements between pockets. The analyses from the tetrahedrite vein that join the cluster of points at the top of this diagram are from gemmy red areas in the crystal, whereas those that have high Fe located near the central bottom of the diagram are from a more opaque, pink-colored rim. Those pockets showing the greatest deviation from pure $MnCO_3$ are the Tight Pocket, Rainbow Pocket, Empty Pocket, and Red and Blue Pocket. Several of the pockets, including the Good Luck, have minor cracks in gemmy rhodochrosite filled with low-quality rhodochrosite. However, in the case of the Good Luck pocket, the major contaminant is Mg, not Fe, and the high quality of the Good Luck pocket rhodochrosites testifies to the fact that a small increase in Mg, as shown in this diagram, does not produce ugly rhodochrosites. In contrast, though, high Fe does.**

structure significantly reduces the value of the specimens. Such knowledge is guiding exploration for new pockets—mine workings are preferentially drifted along structures that do not contain evidence of low temperature, pink rhodochrosites.

DISCUSSION

Ca, Mg and Fe^{+2} substitute for Mn, and most analyses of rhodochrosite show small amounts of these ions. Furthermore, Goldsmith and Graf (1960) and Fubini and Stone (1983) were successful in precipitating a complete solid solution series running from well-crystallized calcite to well-crystallized rhodochrosite at room temperature. However, relatively pure $MnCO_3$ is rare in nature; an analysis of a "rosy rhodochrosite" from the Ljubija district, Bosnia is considered to be "among the purest recorded" (Deer *et al*., 1962). This analysis from the Ljubija district shows 0.60% Fe and 0.36% Ca. In contrast, samples from the Sweet Home mine Good Luck Pocket only contain 0.14% Fe and 0.03% Ca (Table 7). Likewise, data from the Corner and Coors Pockets also show low concentrations of Fe and Ca. Therefore, it is no surprise that the Sweet Home mine has produced the most gemmy, cherry-red rhodochrosite in the world. In contrast, an analysis of "yellowish gray ferroan-zincian rhodochrosite (capillitite), associated with pink rhodochrosite in stalactitic cavities in pyrite-sphalerite-galena vein," from the famous Capillitas, Catamarca, Argentina, shows 10.8% Fe, 2.4% Ca, and 11.6% Zn (Deer *et al*., 1962). Elsewhere in Colorado, "taffy-colored" ferroan rhodochrosite ("oligonite") from Leadville contains 20.3% Fe (Deer *et al*., 1962).

CONCLUSIONS

No other locality in the world has produced rhodochrosite with such a low Fe+Mg+Ca content. This low level of contamination is what has given the Sweet Home mine the distinction of producing the finest specimen and gem rhodochrosite in the world. Substitution of Fe+Mg+Ca for Mn in the rhodochrosite structure reduces specimen value. However, the primary polluter is Fe. Effects of Ca and Mg on specimen quality are generally minor. During mining activities, areas showing the high Fe+Mg+Ca low-temperature signatures should be avoided.

After reviewing all of the samples analyzed from the Sweet Home mine and plotting their results on a mine map, it is clear that there are areas within the mine that consistently show the low Fe+Mg+Ca signatures. These signatures define areas where higher-temperature and higher-value, cherry-red rhodochrosite may be found. Thus, microprobe analysis has proven itself to be a valuable exploration tool. Using this tool, the mining company can limit its exploration efforts to areas within the mine that exhibit the low Mg+Fe+Ca high-temperature signatures.

Ancient Fluids at the Sweet Home Mine

T. James Reynolds
FLUID INC.
P.O. Box 6873
Denver, Colorado 80206

INTRODUCTION

Geologists study mineral deposits in the hope of discovering nature's secret methods of ore formation. Such knowledge is then put to use in exploration for mineral concentrations that can be mined at a profit. For nature to concentrate elements dispersed throughout the crust of the Earth into an ore deposit involves a physical agent that gathers, transports, and deposits the elements in a restricted volume of rock. The transporting agent commonly employed by nature is water. Thermal gradients in the rock cause water to move—just as hot air rises, water heated by a local magma will rise through pores and fracture networks in rocks. Zones of rock with the highest permeabilities will permit a greater amount of fluid to pass through them. Physical processes (such as boiling, cooling, mixing of waters from different sources) or chemical processes (such as reaction of the water with the rock) that alter the circulating water may cause mineral precipitation. Thus, the focusing of hydrothermal fluids, laden with dissolved mineral constituents, through restricted volumes of rock where precipitation mechanisms are functioning over a protracted period of geologic time is the method by which nature makes mineral deposits.

The subdiscipline of geology devoted to the understanding of the physical and chemical processes responsible for ore deposition is known as economic geology. The specimen shown in Figure 190 can be considered ore, as it brought wealth to the miner who removed it from the pocket where it formed. It now resides as the opening exhibit to the Denver Museum of Natural History Coors Mineral Hall for all in the world to enjoy. To view the "Alma King" in person is exhilarating—it is truly one of nature's masterpieces. No doubt, the emotional impact of these beautiful rhodochrosite crystals will inspire many people to wonder how they came to be.

Having studied economic geology for some 17 years, I was both ecstatic and grateful for the opportunity to discover the origins of one of the most spectacular mineral specimens in the world. Incredibly, the Sweet Home mine yielded a suite of samples for study that is unparalleled in my entire career. This article describes what one economic geologist has discovered about the unique processes responsible for nature's art found at the Sweet Home mine.

Not all mineral deposits form from hot, circulating waters. However, those minerals that do form through precipitation from aqueous solutions commonly enclose tiny bits of the hydrothermal fluids within crystal imperfections. These fluid-filled cavities are known as *fluid inclusions* and provide an economic geologist with an ancient time capsule from which the temperatures, pressures, original compositions, and densities of the original fluids can be discovered. Such information about the fluids which formed the crystals is crucial for deciphering the physical and chemical processes of ore formation. The fundamental principles, limitations and methodologies of the fluid inclusion technique can be gleaned from a recent text by Goldstein and Reynolds (1994). To understand this article, all that needs to be appreciated is that a fluid inclusion can yield a minimum temperature at which it was entrapped; in addition, unequivocal information about the composition of the hydrothermal fluid enclosed within the inclusion can be determined. Such data are obtained from doubly polished sections about 100 microns thick within a heating/cooling stage mounted on a petrographic microscope. Minimum temperatures of

***Figure 190.* Paragenesis at the Sweet Home mine as displayed by the "Alma King" in the Coors Mineral Hall, Denver Museum of Natural History. Two large crystals of rhodochrosite are perched on top of earlier euhedral quartz crystals and black sphalerite. Purple fluorite and calcite are the latest minerals. Width of the large rhodochrosite crystal is 5.5 inches.**

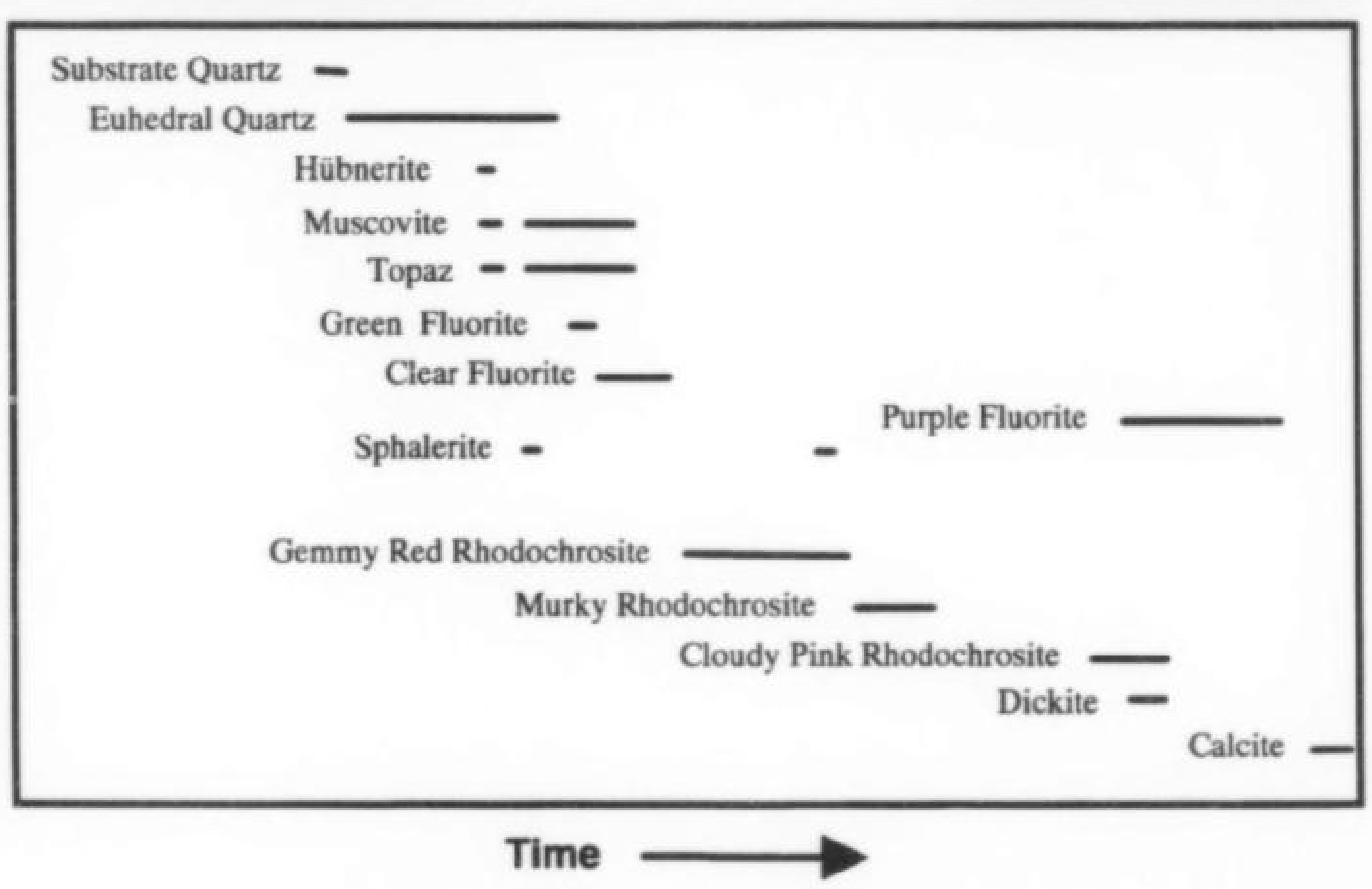


***Figure 191.* Generalized paragenetic relations among minerals at the Sweet Home mine as determined from polished thick sections and hand specimens of many samples collected from veins and vugs within 50 meters of the Rainbow Pocket. (Progression of time from left to right.)**

entrapment are determined by heating an inclusion until liquid, vapor, and salts of chloride that have separated out within the inclusion cavity become homogenized again into a single phase. Compositions (such as salinity and gas compositions) are obtained through interpretations of the temperatures of phase changes (such as ice melting) that occur upon freezing and then warming a frozen inclusion.

For effective and efficient use of fluid inclusions the experienced economic geologist begins by asking pointed scientific questions. The petrographer then identifies those minerals useful for fluid inclusion studies and determines their paragenetic relationships. This is followed by a broad reconnaissance survey using the microscope. In this survey one learns whether the inclusions required to answer the questions posed are present. If so, they are

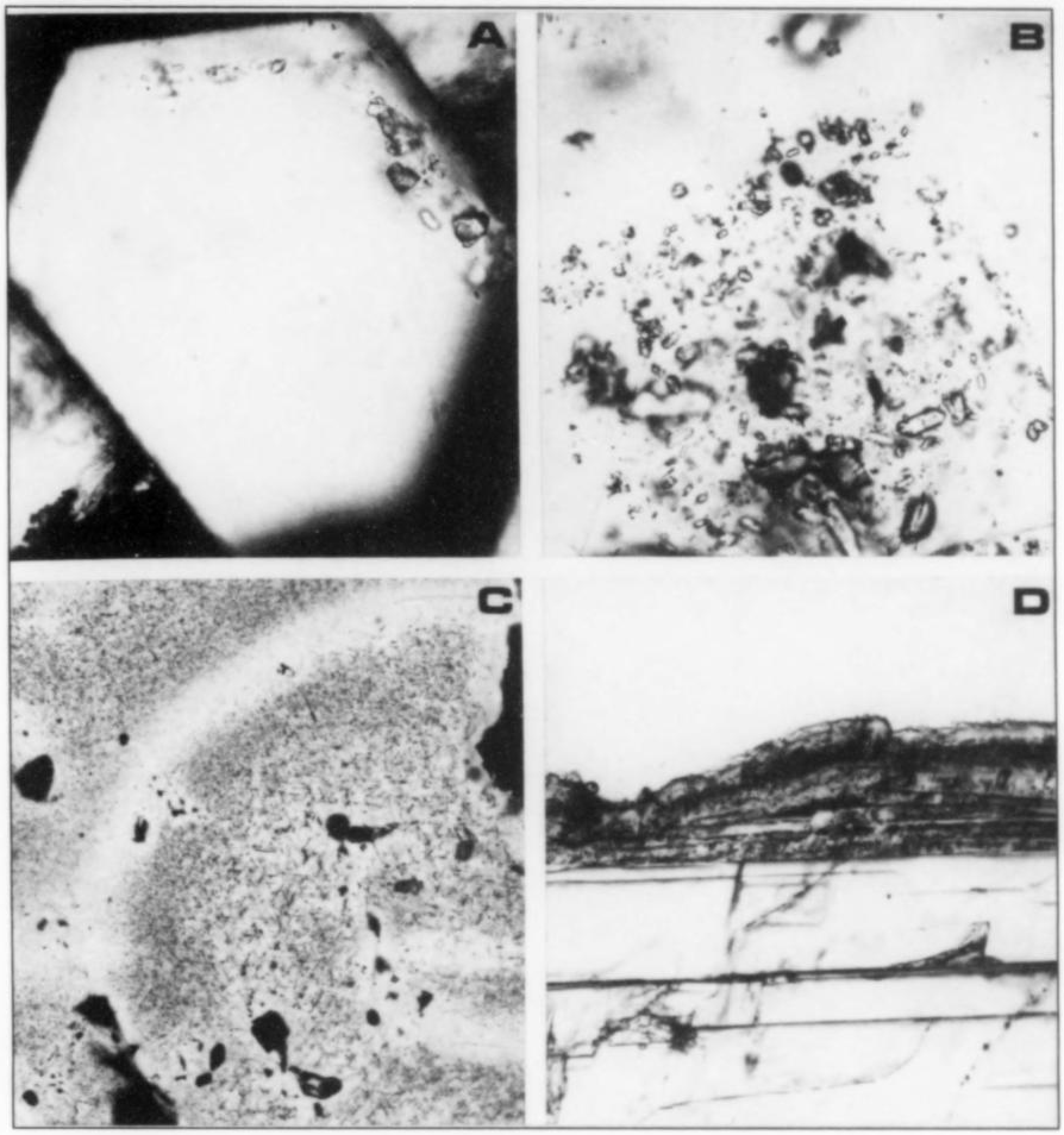


Figure 192. **Photomicrographs of polished thick sections showing growth zoning in crystals delineated by inclusions. Each plate is about 1 mm across. *(A)* Solid inclusions of topaz and muscovite in quartz. *(B)* Square-shaped core of a fluorite crystal with abundant topaz solid inclusions. *(C)* Growth zoning in sphalerite caused by solid inclusions of unknown mineral. *(D)* Dark, banded outer growth zones of rhodochrosite. These growth zones are due to abundant fluid inclusions as shown in Figure 193-E.**

subsequently heated and cooled for data collection followed by interpretation.

THE QUESTION

How nature made the Sweet Home rhodochrosite can be translated to the question: "What are the physical and chemical processes responsible for formation of the crystal-rich pockets?" With respect to the fluid inclusions, the question becomes: "What are the minimum temperatures and compositions of the hydrothermal fluids from which the minerals in the veins and vugs formed at the Sweet Home mine?" If these parameters can be determined, an attempt can then be made to decipher information about the physical/chemical environment of formation, and the processes that may, or may not have occurred.

THE REQUIREMENT

For the rocks to contain the information necessary for us to learn about conditions of mineral formation, fluid inclusions must have formed during mineral growth and must be preserved in the crystals. Specifically, fluid inclusions showing unequivocal evidence of entrapment during crystal growth are prime candidates for detailed study.

THE PARAGENESIS

Understanding that it is a geologic process that the economic geologist is trying to decipher, and realizing that a process is something that occurs through time, the geologist needs some kind of information that provides a demarcation of time. Mineral paragenesis (order of mineral growth) provides a record of relative

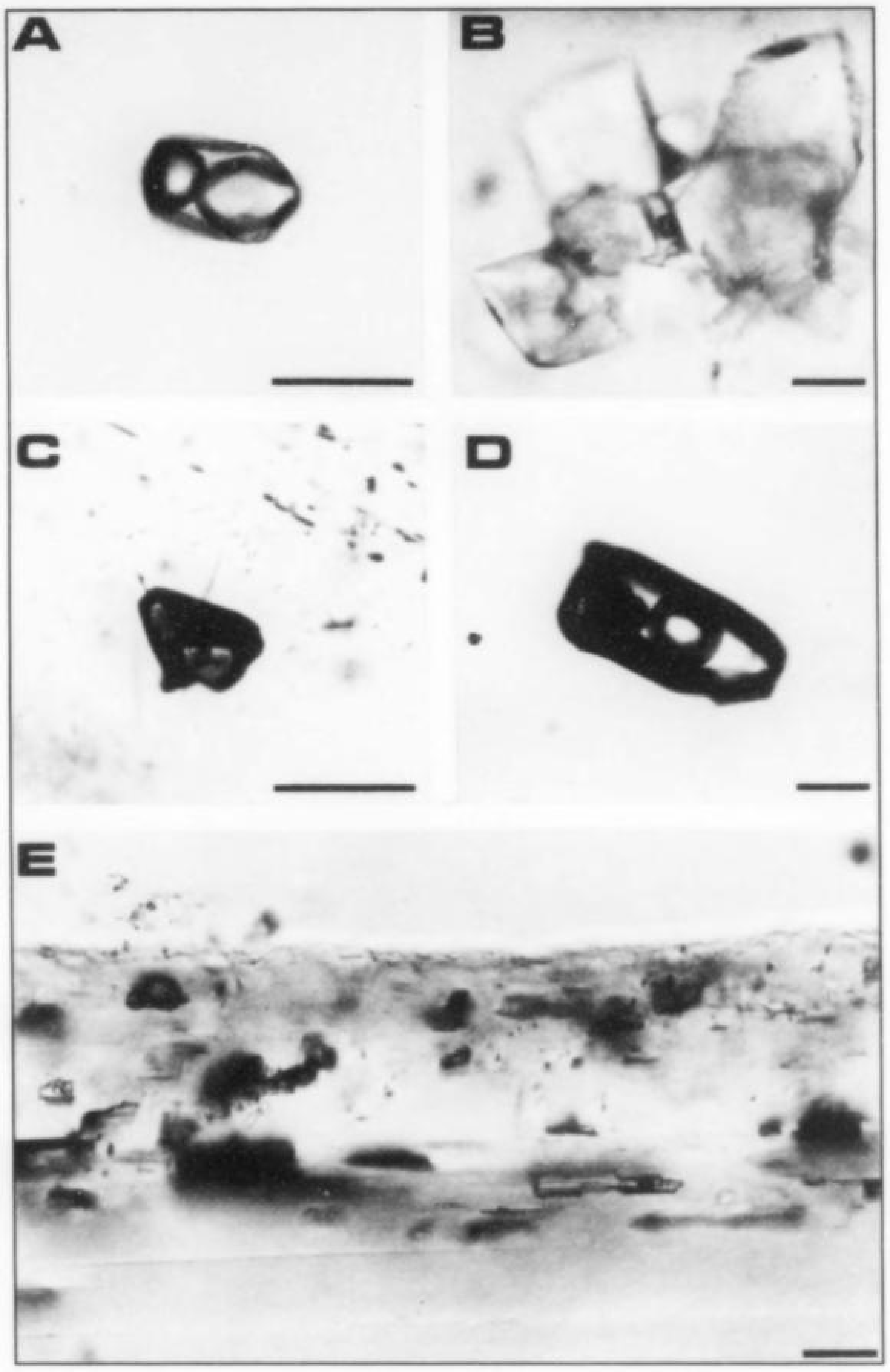


Figure 193. **Photomicrographs showing evidence of fluid inclusion origins. Scale bars are 0.01 mm in length. *(A)* Inclusion in quartz trapped next to a solid inclusion of topaz. Dark round feature on left is a bubble, probably containing CO_2 gas. *(B)* Inclusion in fluorite trapped between crystals of topaz and muscovite(?). *(C)* Inclusion in sphalerite trapped next to solid opaque inclusion. *(D)* Inclusion in rhodochrosite trapped next to solid opaque inclusion. *(E)* Outer cloudy growth zone coating clear rhodochrosite crystal. Note that cloudiness is due to abundant fluid inclusions.**

progression of time, and as demonstrated in Figure 190, the specimens of the Sweet Home mine distinctly display an order of mineral growth. Several dozen specimens collected in various pockets and crosscuts within 50 meters of the Rainbow Pocket (from which the "Alma King" specimen was collected) were carefully studied, both in hand sample and on polished section. Figure 191 shows generalized paragenetic relationships. One important feature of the paragenesis apparent throughout the mine is that rhodochrosite always follows the greisen alteration assemblage composed of quartz, muscovite, topaz and fluorite. These episodes of mineralization are referred to as stage 1 and stage 2 mineralization in other papers of this issue. Some individual samples might show the entire sequence of events, whereas others might have only one or two minerals. For instance, in rare pockets, only quartz, pyrite and hübnerite are abundant. In others gemmy red rhodochrosite crystals sit on a black substrate of sphalerite. Which minerals are present in which pockets was probably controlled by the timing of opening and closing of the individual pockets. Therefore, the structural evolution must be of great significance in dictating spatial positioning of the different mineral phases, and thus should be of keen interest to explorationists. However, structural geology is beyond the scope of this article, and will not be mentioned further.

THE SURVEY

About 20 prepared samples were microscopically surveyed to locate suitable fluid inclusions. Abundant inclusions trapped during crystal growth were found in quartz, sphalerite, fluorite, and rhodochrosite. Many inclusions define growth zones in the crystals (Fig. 192) thus linking them to processes of crystal growth. Some are solid inclusions, or minerals that were growing on the surface of a growing crystal. Figure 192A shows a growth zone defined by solid inclusions of topaz and muscovite in a quartz crystal. Other growth zones contain hübnerite or sphalerite. Figure 192B is a photomicrograph of a square-shaped fluorite crystal core delineated by abundant solid inclusions of topaz. Figure 192C shows growth zoning in sphalerite, and Figure 192D shows a gemmy rhodochrosite crystal coated by cloudy rhodochrosite (Mn-poor; see Wenrich, this issue). Such cloudy, inclusion-rich rhodochrosite is common as a coating on poor-quality rhodochrosite specimens. In contrast to the above examples, this growth zone is defined by abundant fluid inclusions as discussed below.

The presence of solid entities on the surface of a growing mineral commonly causes imperfect crystal growth. In some cases the growing crystal encloses not only the solid inclusion, but traps a little fluid as well. Such an occurrence is of great good fortune to the economic geologist. Fluid inclusions trapped next to solid inclusions defining growth zones (Fig. 193) is the prime evidence required to document that the fluids in the inclusions being studied were indeed the ones present during growth of the enclosing minerals. Figure 193A shows an aqueous inclusion in quartz trapped next to a topaz crystal. A similar type of aqueous inclusion is trapped between solid inclusions of topaz (and muscovite?) crystals in fluorite (Fig. 193B). Figure 193C documents an aqueous inclusion next to an opaque inclusion in sphalerite; a similar inclusion trapped next to an opaque inclusion in rhodochrosite is shown in Figure 193D. Without a doubt, inclusions trapped during crystal growth are abundant at the Sweet Home mine.

RESULTS

Of the thousands of Sweet Home inclusions observed, only one type of inclusion was seen in all samples studied: in this type, all inclusions are two-phase, liquid-rich aqueous inclusions whose vapor bubble disappeared upon heating. No vapor-rich inclusions were ever found, nor were any inclusions found that contained liquid CO_2 at room conditions, nor were inclusions found that contained a crystal of halite. As explained below, when observations at the Sweet Home mine are compared to observations from many other types of ore deposits throughout the world, the absence of these other types of inclusions is significant.

The fluid inclusions were heated and cooled with a convective-style heating/cooling stage on a microscope, which is currently standard equipment in most geology departments worldwide. All procedures, caveats, and strategies dictated in the text by Goldstein and Reynolds (1994) were employed. The data are summarized in Figure 194 and reviewed below.

A fluid of unique composition is found in higher temperature inclusions. All inclusions yielding homogenization temperatures above 250°C show final melting of ice between about –4 to –4.5°C

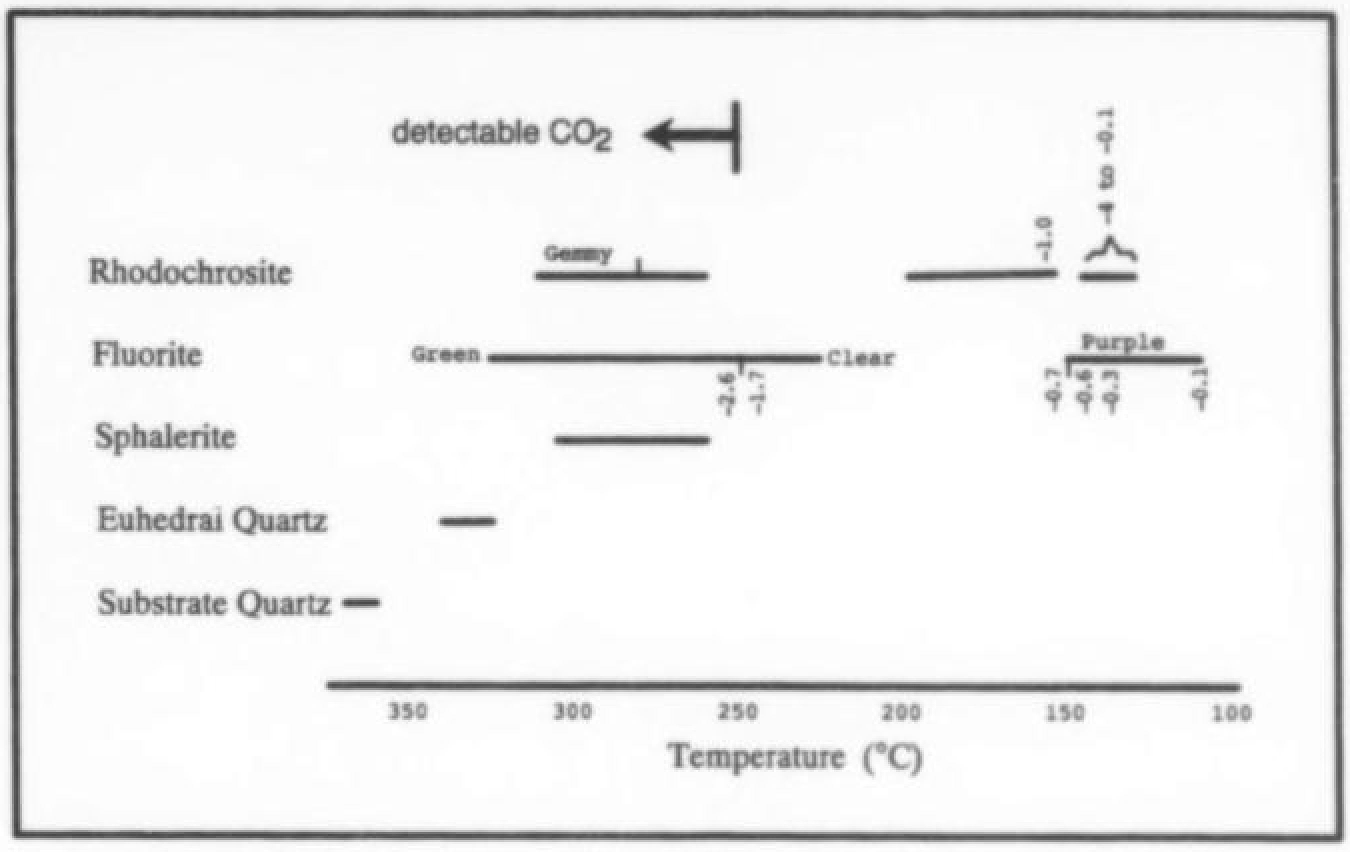


Figure 194. **Generalized portrayal of minimum temperatures of formation of various minerals, and compositional data (final melting points of ice in °C) of fluids from which they grew. All data are from primary fluid inclusions.**

and –2.6°C, and also show evidence of another phase that persisted in the inclusions to temperatures as high as +8°C. It is surmised that this other phase, which melts at temperatures greater than 0°C, is the CO_2 clathrate compound (hydrated CO_2: $CO_2 \cdot 5.75H_2O$), indicating the presence of a significant amount of CO_2 gas (1–2 mole% CO_2?) within the inclusions. The salinities of these CO_2-bearing fluids were determined to be about 2–4 weight % NaCl equivalent by methods described in Bakker (1997).

At about 250°C, as evidenced by inclusions in fluorite, the inclusions rapidly become more dilute, to such an extent that below 250°C there is no evidence of CO_2. Also, salinity decreases progressively from about 3.5 weight % NaCl equivalent to virtually pure water in fluid inclusions at the margins of fluorite crystals.

The highest temperature data (360–370°C) are from fluid inclusions in the centers of quartz crystals in vein material coating walls from which the euhedral quartz crystals emanate. Late growth zones in euhedral, open-space-filling quartz, defined by solid inclusions of hübnerite, muscovite and/or topaz, yield temperatures of 325–340°C. The highest-temperature (about 325°C) fluorite crystallized with the greenest color. Sphalerite solid inclusions could also be found in quartz crystals, but associated fluid inclusions were not found. Temperature data from sphalerite range from about 260–305°C.

Once greisenization ended, rhodochrosite precipitation began. The highest temperature (about 280–310°C) rhodochrosite found (from the Good Luck Pocket and Watercourse Drift) were the most transparent, deepest red crystals studied. More murky rhodochrosite crystals like those of the Alma King specimen yield lower temperatures (255–280°C). The last cloudy pink stage coating many rhodochrosite crystals (greatly decreasing their monetary and aesthetic value) formed at 130–145°C (minimum), dominantly from dilute fluids; however, one growth zone studied contains higher salinity fluids, much like those found in the earlier, high-temperature (>250°C) fluid inclusions. There must have been a late pulse, containing fluid similar to that of the early higher-temperature fluid, that attained the ambient temperature of the surrounding rocks and mixed with the ground water to precipitate the latest impure (see Wenrich, this issue) murky pink rhodochrosite. The latest purple fluorite (sometimes encapsulating dickite crystals) precipitated from very dilute H_2O at temperatures as low as 112°C.

CONCLUSIONS

The fluid inclusions attest to the fact that mineralization at the Sweet Home mine formed from a hydrothermal system that achieved temperatures at least as high as 370°C, which then gradually dropped to as low as about 110°C. No phase separations (boiling, etc.) occurred and no high-salinity fluids were present. The sequence of mineral precipitation probably occurred with cooling of the system, and significant dilution began at temperatures below about 250°C. These conclusions are unequivocal from the fluid inclusion data alone.

Contrasting these data with that from other types of deposits provides clues about the general environment of formation at the Sweet Home mine. The high temperatures (>300°C) and lack of evidence of boiling eliminates shallow (<1.5 km below the ground water table) epithermal environments. The lack of vapor-rich and high-salinity fluids common in and above porphyry-copper and porphyry-molybdenum deposits eliminates these two depositional environments for the Sweet Home mine. The absence of visible liquid CO_2 within the inclusions (common in mesothermal, greenstone-hosted, lode-gold deposits worldwide) argues against the high temperatures being solely a result of great depths. Furthermore, in 17 years of studying fluid inclusions in many types of ore deposits worldwide, I have never studied a locality with the same characteristics found at the Sweet Home mine: (1) only 1 type of fluid inclusion, (2) temperatures as high as 370°C, and (3) high enough CO_2 contents for it to be detectable, but not so high for liquid CO_2 to be visible. Thus, not only do the fantastic mineral specimens which come from the Sweet Home mine dictate that the environment of mineral deposition and the ancient ore-forming processes were unique, but so do the fluid inclusion data.

One possible explanation for these unusual fluid inclusions is that the environment of formation of the Sweet Home mine is above the top of a pluton, but not a pluton like those of porphyry deposits. Because of their sizes and compositions, the magmas of porphyry copper and molybdenum deposits rise to shallow levels in the crust and exsolve magmatic fluids at temperatures and pressures (depths) that reach the two-phase (liquid+vapor) field of the H_2O-NaCl-CO_2 chemical system (Bodnar, 1995; Bodnar and Vityk, 1994). Therefore, these magmatic fluids split into two fluids: (1) a highly saline brine and (2) a vapor. It would be expected that the vapor phase could rise far above a pluton and potentially be trapped within fluid inclusions. Such, in fact, is the case at the Henderson porphyry molybdenum deposit (Kamilli, 1997, personal communication). However, vapor-rich inclusions are not found at the Sweet Home mine. So, if the Sweet Home mine is above the top of a pluton, the magma was either chemically different, causing it to crystallize and exsolve magmatic fluids at lower temperatures, or was deeper, or both—all three scenarios could result in the magmatic fluid never entering the two-phase field, as indicated by the fluid inclusion data. Another possibility for the environment of formation is that the Sweet Home mine is distally related to a shallowly intruded porphyry pluton as suggested by Misantoni and Silberman (this issue). Either way, the unique characteristics of the fluid inclusions and the associated mineral assemblages strongly suggest that the environment of formation was within a realm of fluid flow driven by a plutonic heat source.

In summary, the earliest quartz to precipitate at Sweet Home yielded the highest temperatures. As fractures became more open, the temperature of quartz precipitation dropped and euhedral quartz formed along with, and was then followed by, the classic greisen minerals fluorite, muscovite, and topaz. The cessation of greisenization and the onset of rhodochrosite precipitation is an event that occurred throughout the mine. Mineralization ceased soon after precipitation of late, pink rhodochrosite and purple fluorite.

NOTE:

The observations reported here were made only on specimens collected from a rather restricted region in space. It is of utmost importance to place these observations in a more regional context in order to better constrain the environment of formation as well as the natural processes that resulted in this, the most spectacular rhodochrosite mineral specimen locality in the world.

Crystal Chemistry of Minerals from the Sweet Home Mine

Karen J. Wenrich
Wenrich Petrography * Mineralogy * Geochemistry
P.O. Box 5054
Golden, Colorado 80401

Regina Aumente-Modreski
8075 W. Fremont Drive
Littleton, Colorado 80128

INTRODUCTION

The Sweet Home mine is known to most collectors today for its gemmy red rhodochrosite. However, ask what else comes from the Sweet Home mine and, at best, the answer might be pyrite, fluorite and quartz; few people know of the brilliant orange hübnerite or the microscopic stromeyerite. This was not the scenario last century, when lead-silver mining began at the Sweet Home in 1872. As in so many of Colorado's old silver mines, the silver-bearing veins were elusive and yielded no bonanza. However, the tenacity of miners allowed this mine to operate intermittently for over 120 years. Silver was believed to occur in argentiferous galena (Patton *et al.*, 1912), but the present study shows little Ag in the galena. Rather it occurs in small crystals of the Ag-Cu-sulfide (stromeyerite) and in Cu-sulfides such as digenite, bornite and tetrahedrite. Had previous miners been privy to the information presented in this report they may have been more successful in their quest for silver. The last silver mining occurred in 1966.

An ambitious petrographic/electron microprobe study was undertaken at the Sweet Home mine for two primary reasons: (1) Scientific value—as specimens from this mine circulate worldwide, so will the knowledge of their chemistry and mineralogy. (2) Mineral exploration-geochemical halos and geographic trends in mineral chemistry can indicate favorable zones for rhodochrosite exploration. The success of such exploration research has the potential for enormous financial savings through the resultant increased efficiency in the mining.

A large suite of sulfide, oxide, and silicate minerals is associated with the rhodochrosite in the Sweet Home mine. The minerals at the Sweet Home are unique in contrast to those from most specimen mines because their exact crystal chemistry is known through research supported by Sweet Home Rhodo, Inc. The nagging question to many mineral collectors when buying specimens of minerals such as tetrahedrite is how did the seller/collector verify the specimen to be tetrahedrite—or could it really be tennantite? Electron microprobe analyses for 28 elements were completed on 468 crystals of barite, bornite, chalcopyrite, dickite, digenite, dolomite, fluorapatite, fluorite, galena, hübnerite, illite, jalpaite, muscovite, pyrite, quartz, rhodochrosite, sphalerite, stromeyerite, tennantite, tetrahedrite, topaz and triplite. The intrinsic value of microprobe analyses to the mineralogist lies in the ability of the instrument to produce quantitative chemical analyses of spots that are as small as 2 microns. Details of the microprobe technique used in this study are discussed in the chapter on rhodochrosite color (this issue).

The reproducibility of the electron microprobe analyses can be seen in the table of pyrite analyses—these 7 analyses of samples from 7 pockets were carried out during 5 different microprobe runs over a period of a year; the stoichiometry of the pyrite is excellent and the totals are between 99.0 and 101.1. Because emphasis during the study was placed on intrasample mineral associations and solid solutions, the analyses were completed using one setup for all of the sulfides, oxides, and silicates. Oxygen and fluorine were determined directly and not calculated. Unfortunately, although this worked fine for most minerals (oxygen was dropped from the program whenever an unoxidized sulfide was analyzed), it did not permit the best accuracy for minerals such as fluorite and

Figure 195. **Graph showing the paragenetic sequence for the dominant minerals found at the Sweet Home mine. Note that quartz and pyrite are the earliest-formed minerals, while rhodochrosite and fluorite appear to have formed over a longer period of time and at much lower temperatures. Fluid inclusion filling-temperatures were determined for rhodochrosite, fluorite, quartz, and sphalerite (see Reynolds, this issue); hence, these minerals are more firmly established on the paragenesis sequence than are the remainder of the minerals.**

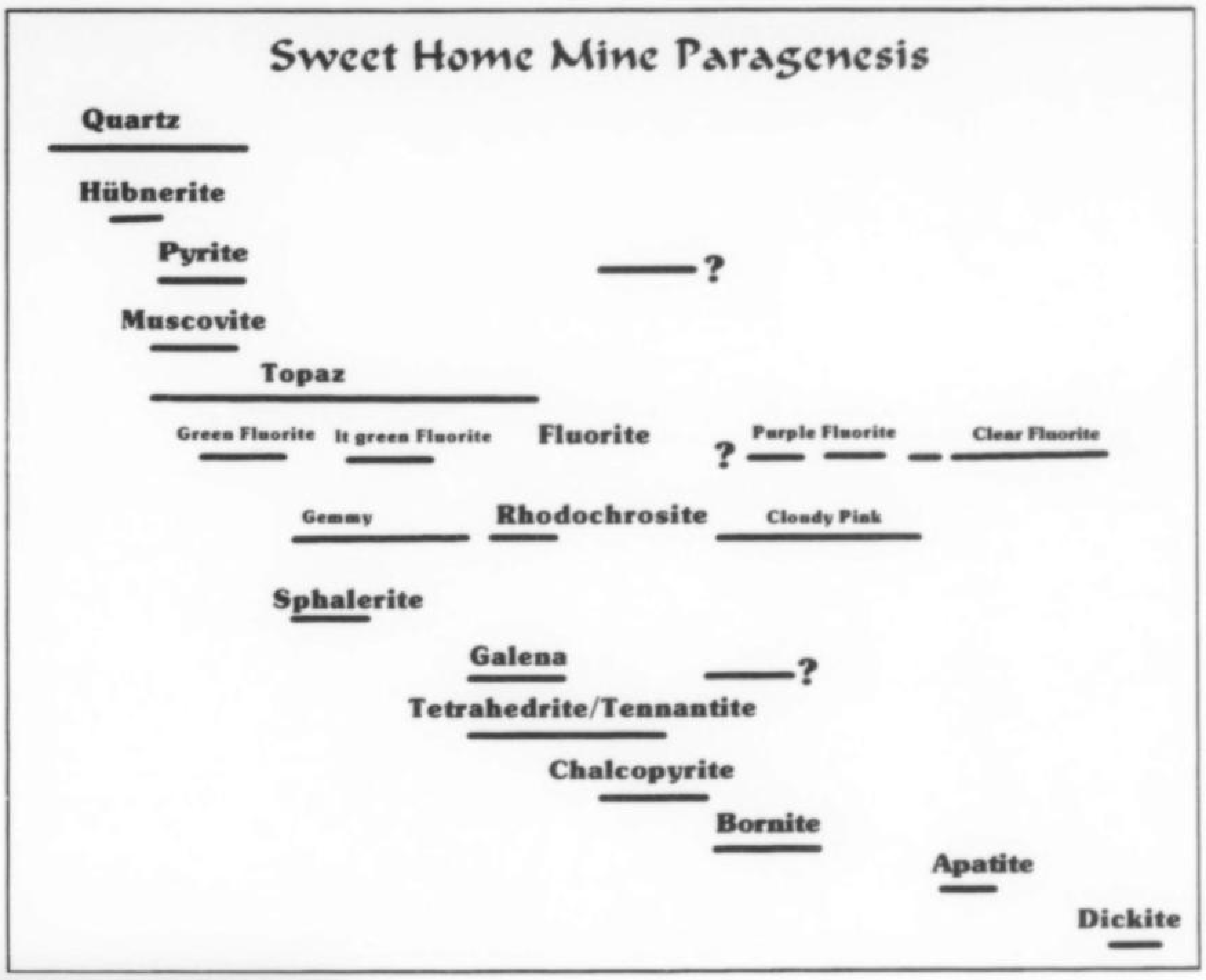
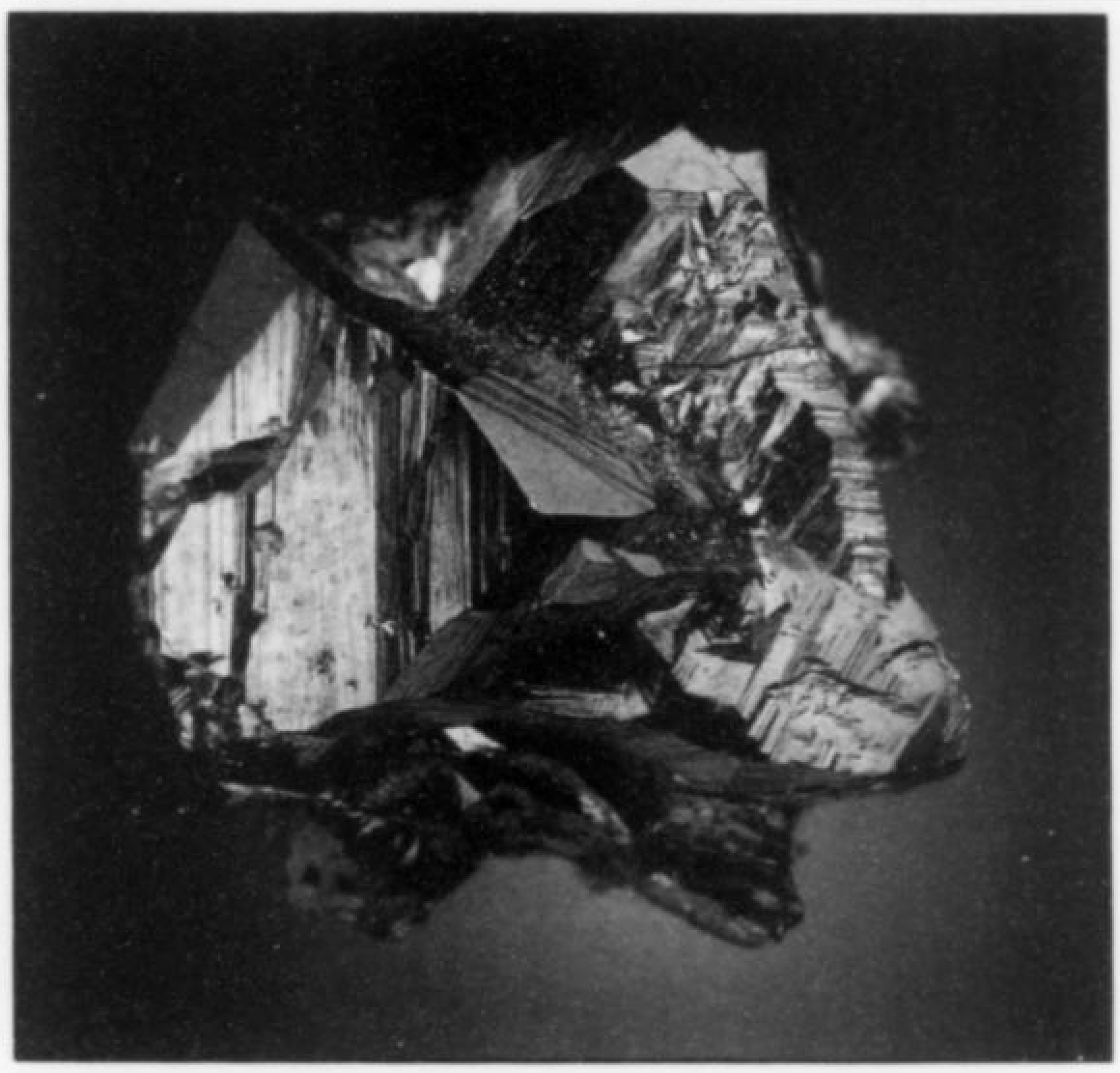


Figure 196. **Tetrahedrite occurs in well-formed tetrahedrons at the Sweet Home mine. Tetrahedrite crystal, 2 cm high, from the Corner Pocket. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**



apatite, which require very precise standardizations for fluorine. However, the results are reasonable, and provide much information about these species that would not normally be available during such an encompassing study.

An abbreviated data table has been provided for each mineral using several representative analyses. Scanning electron microscope backscatter images are provided to demonstrate the degree of solid solution in phases such as tetrahedrite/tennantite and hübnerite. Such images measure the density of the various phases; hence, the higher the atomic number of the elements in the mineral the brighter the image in the photograph.

The minerals have been divided into sulfides, oxides, and silicates and their crystal chemistry is discussed in that order. A literature review and occurrence descriptions for the various species are presented by Murphy and Hurlbut (this issue).

PARAGENESIS

The most prominent minerals at the Sweet Home mine have been placed into a paragenetic sequence of formation based on their interrelationships as observed in hand specimens and their decreasing temperature of formation as measured by T. James Reynolds (this issue). Minerals that can have their temperature of formation calculated from fluid inclusions, such as rhodochrosite, fluorite, topaz, quartz and sphalerite, can be placed into such a diagram as shown in Figure 195 with a fair degree of accuracy. However, the opaque minerals such as pyrite, galena, chalcopyrite, and tetrahedrite/tennantite must be worked into the paragenetic sequence based on their interrelationships as observed in hand specimens, and with those minerals that have measured fluid-inclusion filling temperatures.

SULFIDES

Tetrahedrite/Tennantite $(Cu,Fe,Ag,Zn)_{12}(Sb,As)_4S_{13}$

Tetrahedrite/tennantite is closely associated with rhodochrosite at the Sweet Home mine (Fig. 197). Tetrahedrite (Fig. 196) is more common at the Sweet Home mine than tennantite, but both are present. Modreski (1988) analyzed two samples on the scanning electron microscope and both proved to be tennantite. An almost complete solid solution exists between tennantite (100% arsenic end-member) and tetrahedrite (100% antimony end-member) at the Sweet Home mine. Forty-nine analyses from 7 geographically separate locations show that the tetrahedrite/tennantite spans a range from $Sb_{02}As_{98}$ to $Sb_{91}As_{09}$ (Fig. 199). Such compositional variation is not only present on a large scale throughout the mine, but on a small scale as well; individual crystal clusters may vary through as much as 60% of the solid solution series. The microscopic nature of the intergrowth of these sulfosalts can be seen on the electron backscatter image shown in Figure 198 and Table 8 where 100-micron crystals vary in composition from $Sb_{51}As_{49}$ (spot 10 on Fig. 198) to $Sb_{89}As_{11}$ (spot 23 Fig. 198). Because electron backscatter images are based on atomic weight of the elements

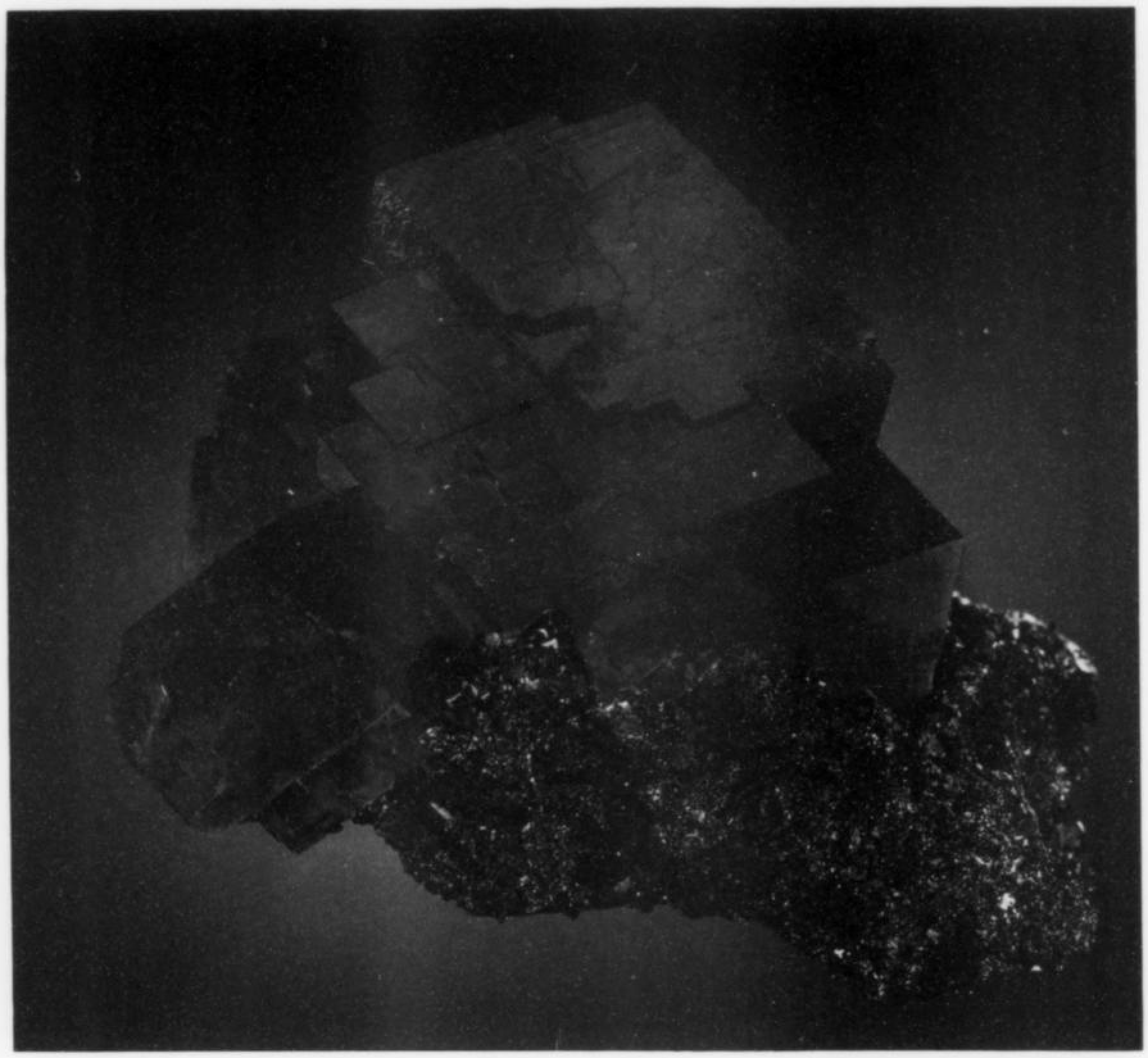


Figure 197. **Zincian tetrahedrite/tennantite is closely associated with rhodochrosite. Rhodochrosite crystal: 7.5 cm high, from the Good Luck Pocket. Martin Zinn collection; photo by Harold and Erica Van Pelt.**

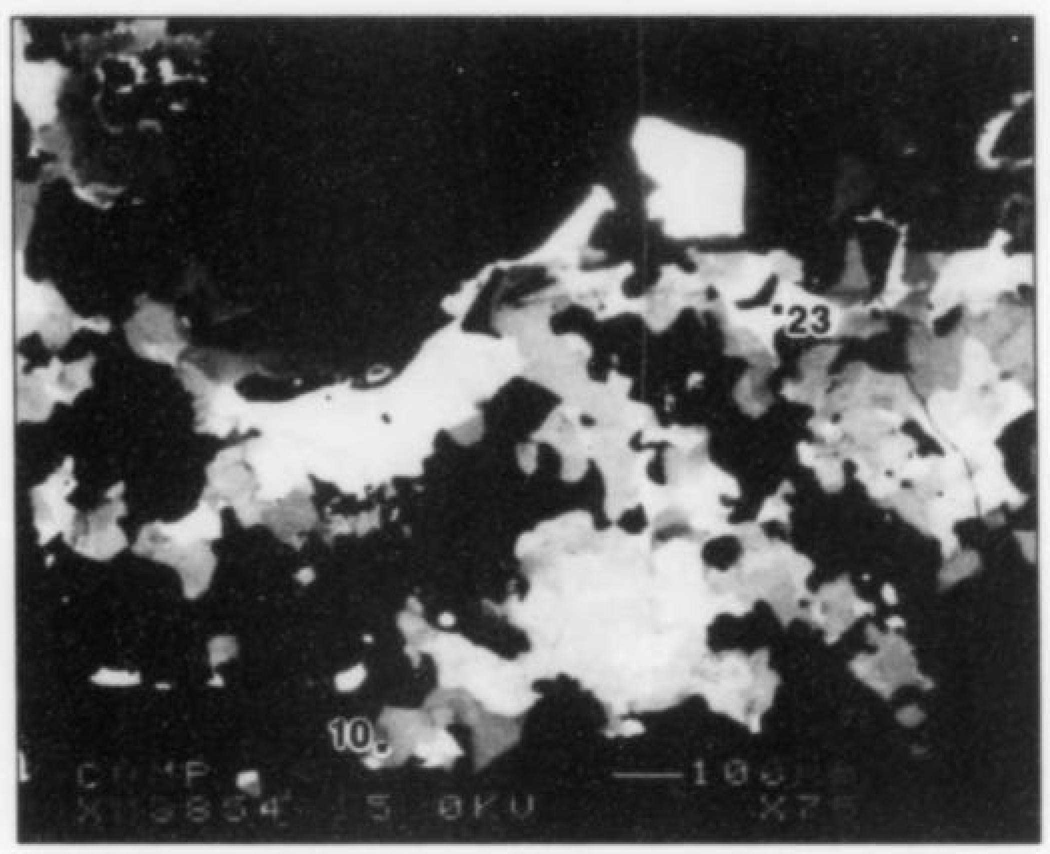


Figure 198. **Scanning electron backscatter image of tetrahedrite from the Watercourse Vein, Corner Pocket. Note the various shades of gray to white (bright white grain at the top is galena). Since the brightness of such an image is dependent on the density (atomic number) of the elements present, the brighter the tetrahedrite the more antimony and less arsenic it contains. The dot marked #10 contains $Sb_{51}As_{49}$ and the dot marked #23 contains $Sb_{89}As_{11}$ (see Table 8 for compositional variation of the tetrahedrite). Sample 4-E-L94, Area A (see third and fourth analyses shown in Table 8). Photograph by Karen Wenrich.**

Table 8. **Selected electron microprobe chemical analyses for tetrahedrite/tennantite. Values are in weight percent. Al, Ba, Ca, Cd, Co, Hg, K, Mg, Mn, P, Se, Si, Ti, V, and W were also determined, but all were less than 0.03%.**

Sample Number	*As*	*Sb*	*Cu*	*Zn*	*Fe*	*Ag*	*Pb*	*S*	*Total*
Good Luck Pocket (2-B-L94 spot X16)	19.8	0.6	43.9	8.7	0.2	0.09	<.03	28.6	102.2
Main Stope (S105 spot A8)	13.3	8.6	41.0	7.8	0.2	0.13	0.12	26.9	98.0
Watercourse Vein (4-E-L94 spot A10)	9.2	15.5	40.4	7.2	0.6	0.68	<.03	26.9	100.6
Watercourse Vein (4-E-L94 spot A23)	1.9	26.3	37.8	7.0	0.2	1.43	<.03	25.3	97.7
Coors Pocket (5-A-L94 spot X22)	5.5	19.9	39.5	7.8	0.4	0.51	<.03	26.2	99.8
Museum Pocket (6-A-L94 spot A13)	2.7	24.1	38.2	7.7	0.1	1.81	<.03	25.2	101.8
Empty Pocket (9-A-L94 spot A7)	3.7	17.3	38.0	7.8	0.1	0.88	<.03	26.1	98.7

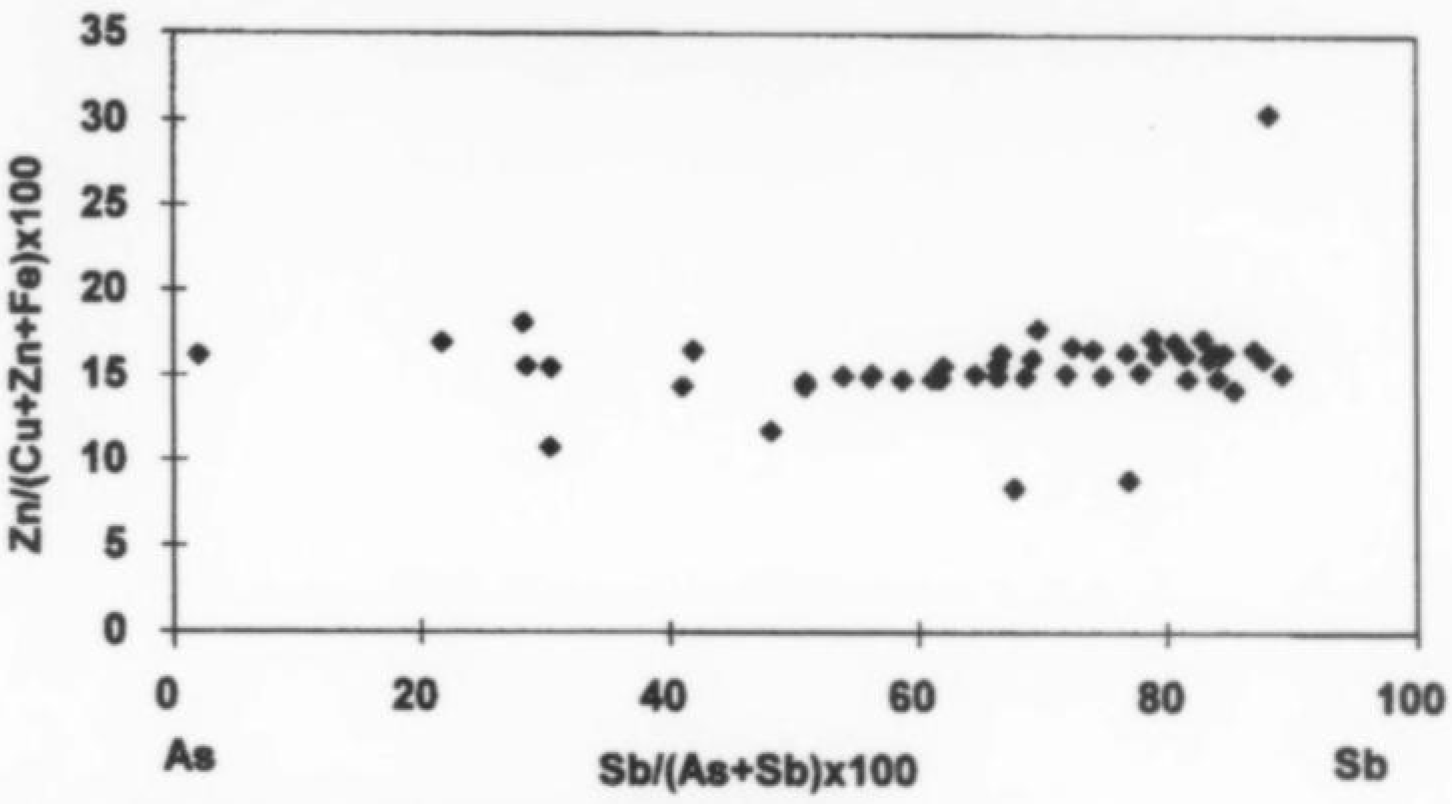


Figure 199. (above) **Graph showing electron microprobe chemical analyses of 49 tennantite/tetrahedrite crystals from samples collected throughout the Sweet Home mine. The x-axis shows the antimony content expressed as a percentage of the total antimony + arsenic. The y-axis shows the zinc content expressed as a percentage of the total zinc + copper + iron. The data used in the diagram are based on elemental atomic percent. The composition of these sulfosalts ranges from $Sb_{02}As_{98}$ to $Sb_{91}As_{09}$. An average of 15% of the copper in the tennantite/tetrahedrite structure is replaced by Zn. Therefore, these phases at the Sweet Home mine are most properly named zincian tetrahedrite and zincian tennantite.**

Figure 200. **The concentration of silver increases with increasing antimony in the zincian tetrahedrite/tennantite series. This graph shows the concentration of silver (Ag) versus antimony (Sb) in the 49 tetrahedrite/tennantite crystals analyzed on the electron microprobe.**

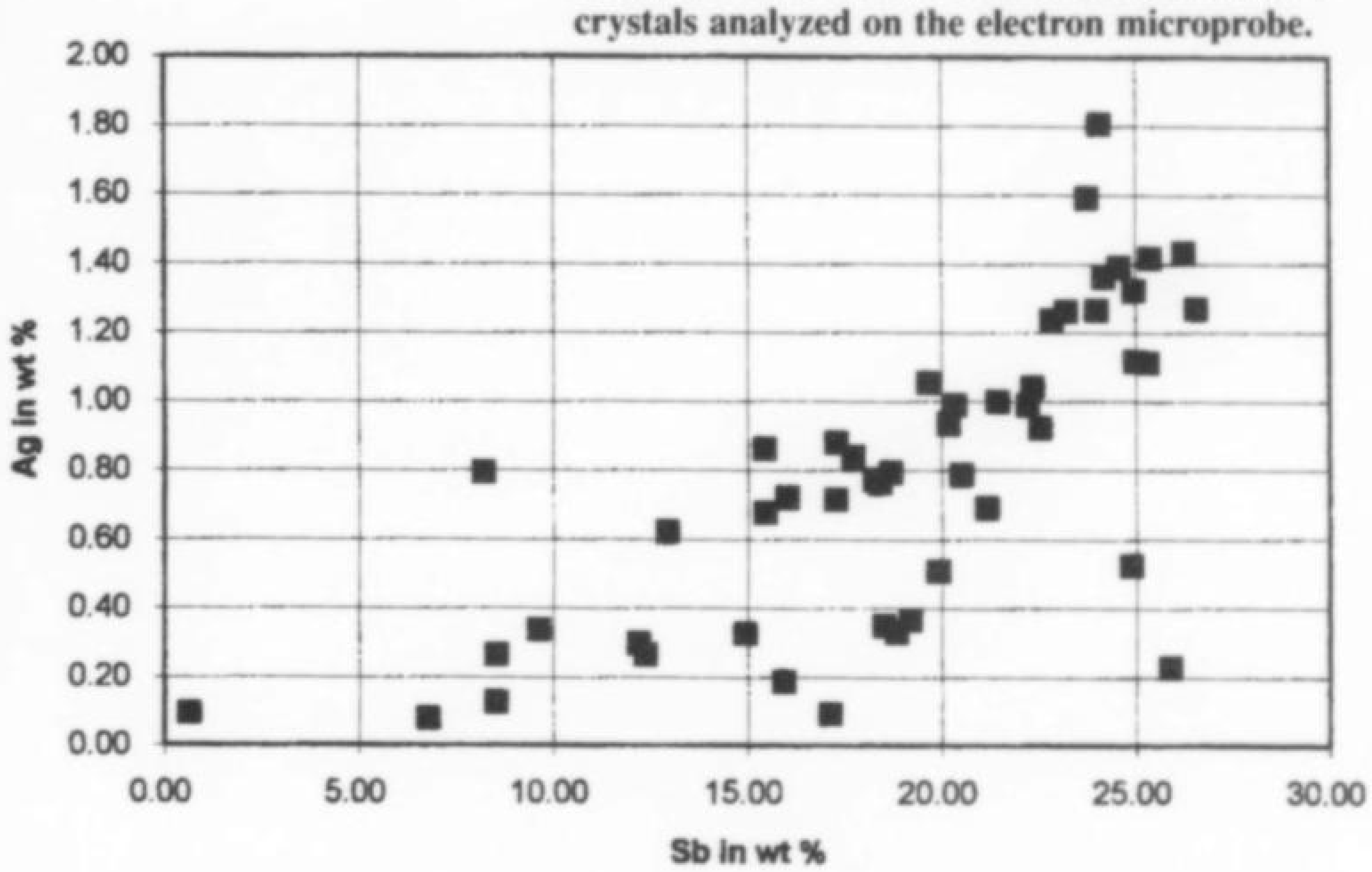


Table 9. **Selected electron microprobe analyses of Sweet Home mine pyrite. Values are in weight percent. Pyrite chemistry is relatively constant between pockets. Other elements determined were Al, As, Ba, Ca, Cd, K, Mg, Mn, Mo, P, Pb, Sb, Se, Si, Ti, V, W, and An; all are present in concentrations <0.08ppm.**

Sample Number	*Fe*	*Co*	*Ni*	*Cu*	*Ag*	*Hg*	*S*	*Total*
Good Luck Pocket (2-B-L94 spot X2)	46.9	0.07	<.01	0.05	0.06	<.01	53.4	100.5
GPR Drift (3-A-L94 spot X1)	46.8	0.11	<.01	<.01	0.04	—	53.7	100.7
Watercourse Vein (4-B-L94 spot B2)	46.8	0.12	0.03	0.05	<.01	<.01	53.3	100.3
Coors Pocket (5-C-L94 spot X12)	47.0	0.03	<.01	<.01	<.01	—	53.2	100.4
Pyrite Pocket (7-A-L94 spot X3)	46.8	0.07	0.05	<.01	0.01	—	53.9	100.9
Red & Blue Pocket (10-A-L94 spot C6)	46.8	0.06	0.02	0.02	<.01	0.33	53.8	101.1
Main Stope (S105 spot X14)	46.2	0.09	0.05	0.04	<.01	0.20	52.3	99.0

present, areas of the photograph that contain sulfosalts that are higher in antimony (atomic number 51), such as spot 10, are brighter than those higher in arsenic (atomic number 33), such as spot 23. So, although the photograph (Fig. 198) provides no information about the absolute As or Sb values, it does permit a qualitative evaluation of the relative As and Sb content between crystals within the intergrowth of tetrahedrite/tennantite.

Some of the silver mined from the Sweet Home mine from 1872 until 1966 undoubtedly was extracted from the tetrahedrite. A direct linear correlation exists between the concentration of silver and that of antimony in tetrahedrite/tennantite (Fig. 200)—Ag substitutes for Cu more readily in Sb-rich tetrahedrite than in the As-rich members of the tetrahedrite/tennantite series. The concentration varies from 1.8 weight % (18,000 ppm) Ag in Sb-rich tetrahedrite to 0.08 weight % (800 ppm) in As-rich tennantite.

An average of 15 atomic % of the copper in the tennantite/tetrahedrite structure is replaced by Zn. Few samples contain Zn concentrations that deviate more than 2% from this 15% substitution for copper. Therefore, this sulfosalt series at the Sweet Home mine is most properly named zincian tetrahedrite or zincian tennantite.

Pyrite FeS_2

Pyrite is by far the most common of the sulfides and also the earliest formed. The crystals are generally euhedral and associated with quartz or other sulfides. It is surprisingly pure FeS_2 with little substitution of other elements, in contrast to Sweet Home mine sulfides such as tetrahedrite and chalcopyrite. Perhaps this suggests that the pyrite finished forming prior to the presence of Cu-Pb-Zn-Mn-As-bearing mineralizing fluids. It is not uncommon for pyrite associated with metal-rich ore deposits to contain several percent arsenic substituting for sulfur, and copper, cobalt, nickel, and zinc substituting for the Fe (K. J. Wenrich, unpublished electron microprobe ore deposit data, 1990–1995). However, electron microprobe analyses of 31 pyrite crystals indicate the concentrations of As, Ni, Pb, Cd, Sb, Ca, Mn, Mg, P, Ba, V, Si, Al, K, Ti, Se and W are <0.02%. Pyrite chemistry is relatively constant between pockets in the Sweet Home mine, and the results show excellent stoichiometry attesting to the accuracy of the electron microprobe data; Table 9 lists the data for 7 of the pockets. Few other transition metals are present in significant concentrations. Mercury is peculiarly high in pyrite samples from the Main Stope and the Watercourse Vein Corner Pocket, reaching as much as 0.86 weight %.

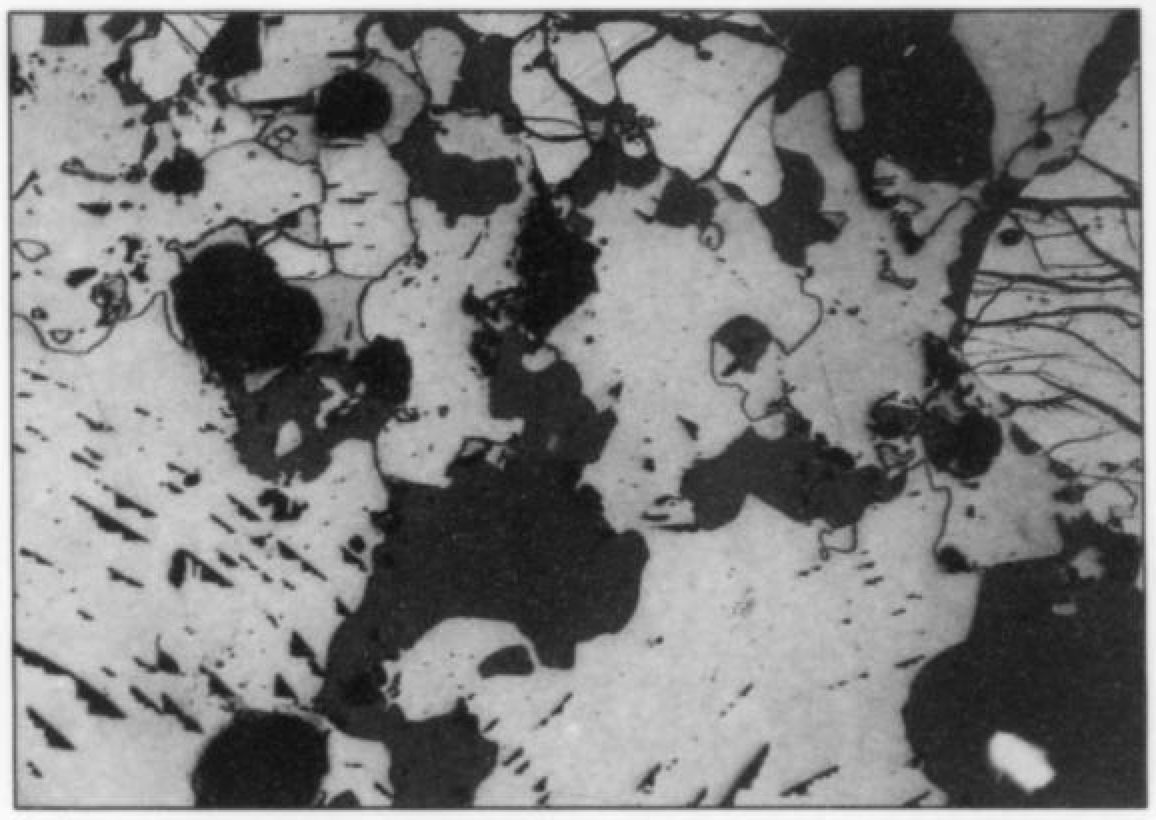


***Figure 201.* Reflected-light photomicrograph of fractured pyrite (yellow) filled with later chalcopyrite (brownish gold) from the Corner Pocket. Some of the chalcopyrite sits on galena (cream with triangular pits), tetrahedrite (greenish blue), and sphalerite (small, darker gray-blue associated with the tetrahedrite). Horizontal field of view is 1.8 mm. Photograph by Karen Wenrich.**

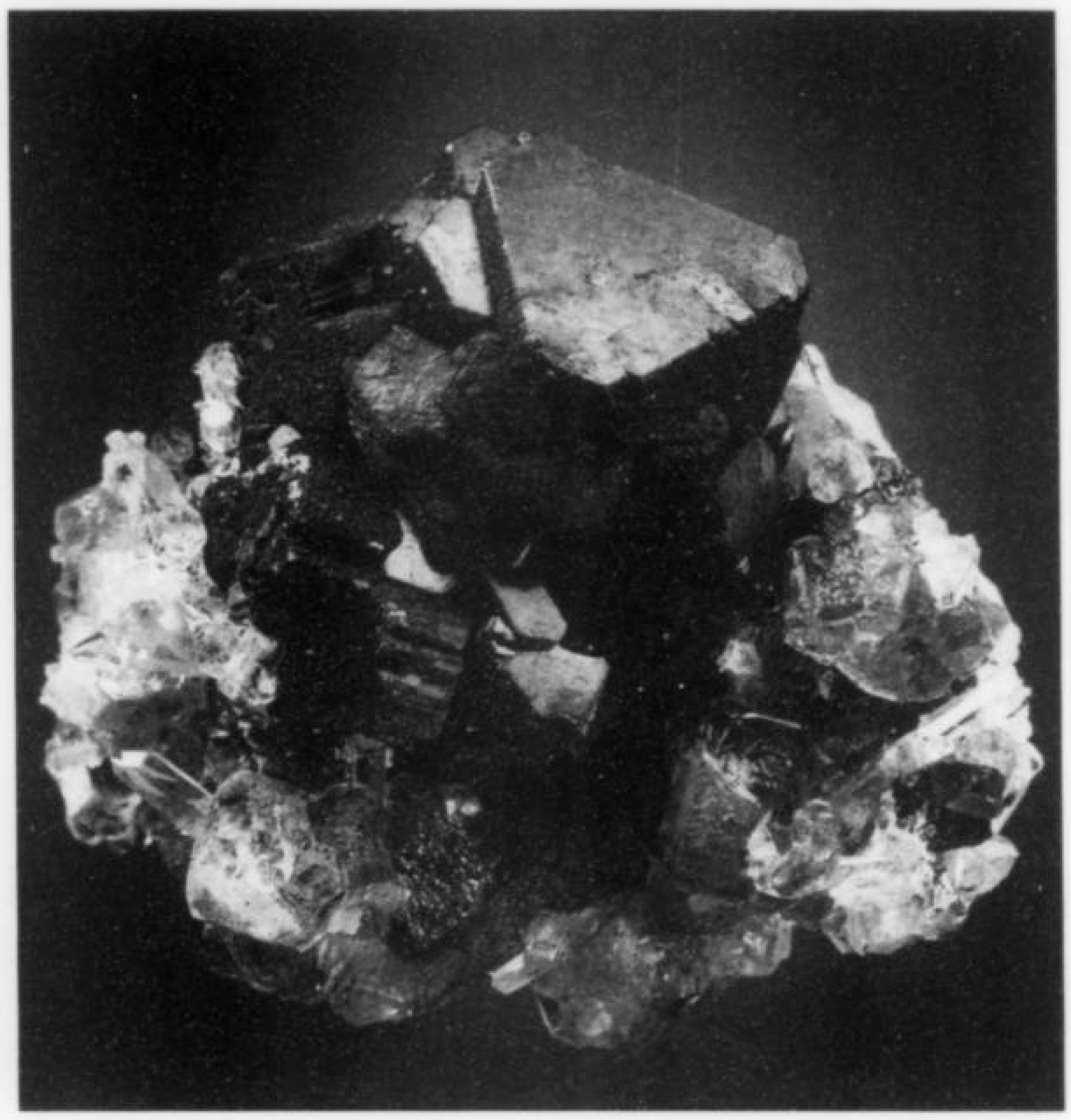


***Figure 202.* Sphalerite commonly occurs as opaque, black tetrahedrons that can be confused with tetrahedrite. This photograph shows the association of sphalerite with fluorite at the Sweet Home mine. Sphalerite crystal, 2.4 cm wide. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

Chalcopyrite $CuFeS_2$

The chalcopyrite formed distinctly later than the pyrite, as can be seen in Figure 201 where the chalcopyrite fills fractures in the pyrite. A significant amount of Zn and Ag have substituted into the chalcopyrite structure in a few samples (Table 10), although in general, the chalcopyrite is pure $FeCuS_2$ for most of the 32 analyses.

Sphalerite ZnS

The sphalerite is moderately pure ZnS in all 56 sphalerite analyses except for very minor substitution of Cd and Fe for Zn

***Figure 203.* Golden orange sphalerite crystal, 9 mm, intergrown with quartz crystals. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

***Table 10.* Selected electron microprobe analyses representative of 30 chalcopyrite crystals. Values are in weight percent. Other elements determined were Al, As, Ba, Ca, Cd, Co, K, Mg, Mn, Mo, Ni, P, Pb, Sb, Se, Si, Ti, V, and W; all are present in concentrations <0.08ppm.**

Location and Sample Number	*Cu*	*Zn*	*Fe*	*Ag*	*S*	*Total*
Coors Pocket (5-B-L94 spot B5)	33.7	3.0	29.5	<0.01	34.8	100.1
Museum Pocket (6-A-L94 spot A7)	34.5	0.2	29.8	1.39	34.4	100.6
Red & Blue Pocket (10-A-L94 spot C7)	33.4	<.01	30.5	<0.01	35.0	99.3

Table 11. **Electron microprobe analyses of sphalerite from the Sweet Home mine. Values are in weight percent and samples are representative of the other 56 sphalerite analyses. Watercourse Drift spot A2 is an analysis of golden sphalerite and spot A4 (see fig. 204), located only 500 microns from spot A2, is colorless and demonstrates no significant compositional difference. Ag, Al, Ba, Ca, Co, Cu, Hg, K, Mg, Mo, Ni, P, Pb, Se, Si, Ti, and V were determined in all 56 analyses, but were consistently <0.03%.**

Sample Number	*Zn*	*Fe*	*Mn*	*Cd*	*Sb*	*W*	*S*	*Total*
Good Luck Pocket (2-B-L94 spot X15)	65.2	0.01	0.05	<.01	0.09	<.01	33.0	101.8
Coors Pocket (5-B-L94 spot C5)	68.7	0.05	0.06	<.01	0.03	<.01	33.2	102.2
Watercourse Drift (8-A-L94 spot A2)	68.1	0.02	0.01	0.26	0.08	0.12	33.3	102.1
Watercourse Drift (8-A-L94 spot A4)	67.9	0.01	<.01	0.19	0.04	0.16	33.2	102.1
Pyrite Pocket (7-A-L94 spot X1)	68.7	0.05	0.06	0.05	<.02	<.01	33.8	102.8
Red & Blue Pocket (10-A-L94 spot C8)	65.5	0.06	<.01	0.11	0.06	0.04	33.1	102.5
Empty Pocket (FI2-A spot A3)	67.3	1.43	<.01	<.01	<.02	0.05	32.4	101.4

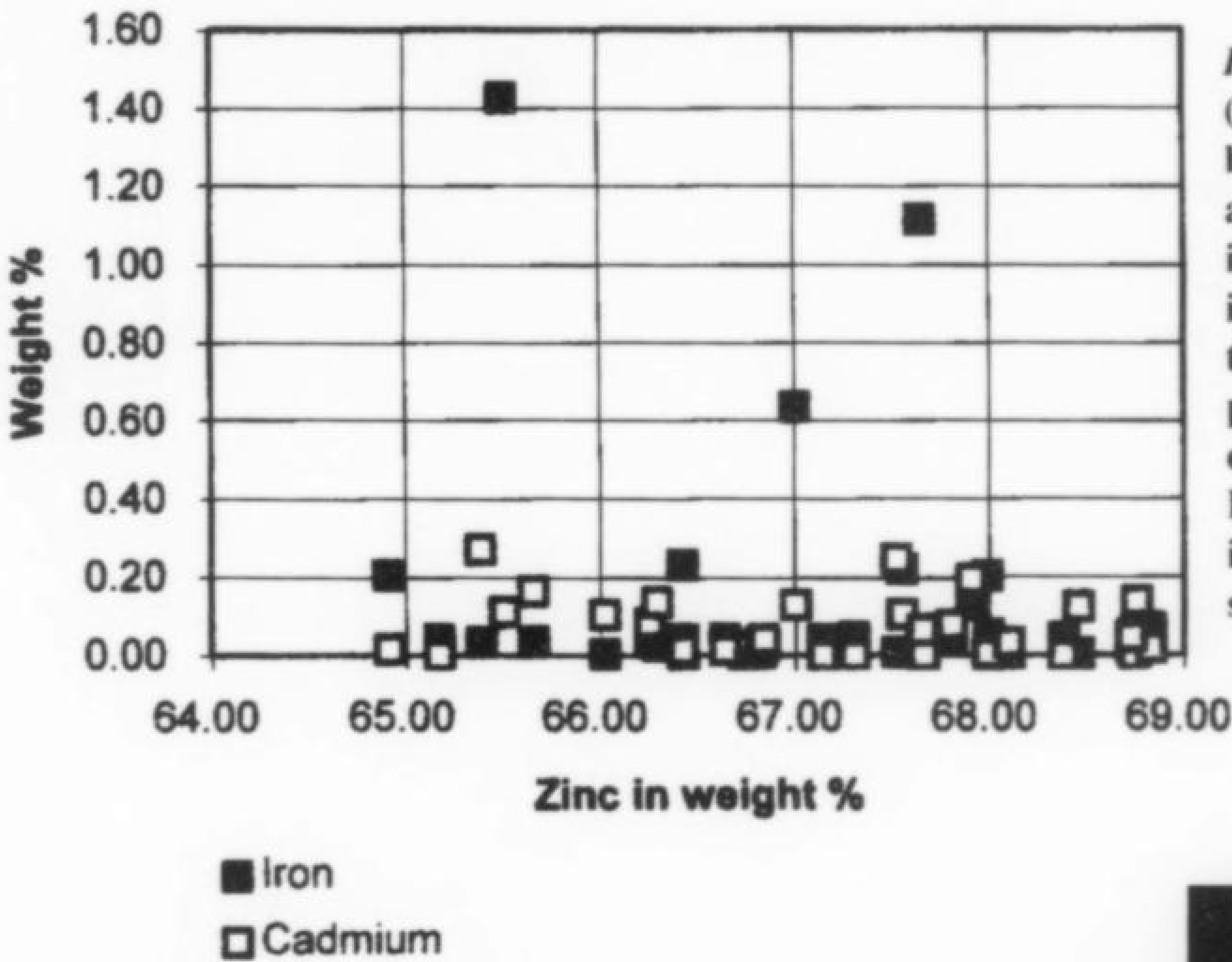


Figure 204. (left) **Graph of Cd and Fe versus Zn (wt. %) in sphalerite. The absence of any correlation between Cd and/or Fe and Zn is an artifact of the analytically insignificant decrease in Zn necessary to incorporate the minor concentrations of Cd and Fe into the sphalerite structure. The percentage drop in the Zn concentration necessary to incorporate 2600 ppm Cd is <1%, which is less than the analytical error of Zn analyses on the electron microprobe. However, the change in the Fe and Cd concentration is several hundred percent, and appears to change systematically through the mine.**

(Fig. 198). Only a very small amount of Fe causes the sphalerite to be opaque (Fig. 202). The compositionally pure sphalerite commonly formed gemmy golden orange (Fig. 203) to gemmy golden yellow crystals. Zones of submicroscopic (<1 micron) opaque needles are aligned within some sphalerite. Other sphalerite is clear and colorless with wispy golden patches. Electron microprobe analyses did not detect any compositional differences (Table 11) between the clear inclusion-free sphalerite and the golden sphalerite. Samples 8-A-L94 spots A2 and A4 are the golden and colorless sphalerite, respectively.

Figure 204 shows a graph of the substitution of Cd and Fe in the sphalerite. Neither element shows a direct correlation with Zn in this figure; this is probably an artifact of the analytically insignificant decrease in Zn necessary to incorporate the trace concentrations of Cd and Fe into the sphalerite structure. The percentage drop in the Zn concentration necessary to incorporate 2600 ppm Cd is less than the analytical error of Zn analyses on the electron microprobe. However, the change in the Fe and Cd concentration is several hundred percent. This change is sufficient to permit recognition of the geographic trend of an Fe increase in sphalerite through the mine. Minor increases in Fe in sphalerite occur in areas where the rhodochrosite is contaminated by Fe, such as in the Tetrahedrite Stope, whereas the Main Stope where some of the purest rhodochrosite resides contains some of the purest sphalerite.

Galena PbS

Galena forms cubes and octahedrons (Fig. 205) at the Sweet Home mine, and is associated with copper sulfides, particularly

Figure 205. **Galena octahedron coated with later chalcopyrite. Galena crystal, from the Rainbow Pocket, is 3.1 cm high. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

Table 12. **Electron microprobe results from analyses of galena representative of the 31 spots analyzed from various galena samples. Values are in weight percent. Ai, As, Ba, Ca, Co, Hg, K, Mg, Mo, Mn, Ni, P, Se, Si, Ti, and V were determined in all 31 analyses, but were consistently <0.03%.**

Sample Number	*Pb*	*Cu*	*Ag*	*Zn*	*Fe*	*Sb*	*S*	*Total*
Corner Pocket (4-A-L94 spot X9)	86.4	0.01	<.01	0.03	<.01	<.01	13.3	100.05
Coors Pocket (5-B-L94 spot D8)	85.7	0.24	<.01	0.78	0.23	<.01	13.7	101.08
Museum Pocket (6-A-L94 spot A1)	87.1	0.07	0.02	<.01	0.04	<.01	13.5	100.80
Pyrite Pocket (7-A-L94 spot X8)	84.5	<.01	0.32	0.70	0.06	0.03	13.6	99.55
Red & Blue Pocket (10-A-L94 spot A13)	84.9	0.03	0.44	0.02	0.06	0.06	13.6	99.76

chalcopyrite and bornite, and the sulfosalt tetrahedrite/tennantite. Although most of the 31 galena analyses show pure PbS, a few contain over 1% Zn. According to Patton and others (1912) "argentiferous galena is the principal mineral mined where the ore is unoxidized." Although electron microprobe analyses show that some galenas from the Tetrahedrite Stope, Main Stope, and Red and Blue Pocket do contain silver, galenas from other areas of the mine contain little to no silver (Table 12). Even where the galena is "argentiferous," the concentration of silver is <0.45 weight %—significantly lower than that contained in most of the copper sulfides, bornite, digenite, and tetrahedrite (Table 8), and certainly less than that in the Ag-Cu-sulfides, stromeyerite and jalpaite (?). Modreski (1988) analyzed several galena crystals on the scanning electron microscope and found no samples with Ag >0.2%.

Bornite (Cu_5FeS_4), **Digenite** (Cu_9S_5), **Spionkopite** ($Cu_{39}S_{28}$), **Stromeyerite** (AgCuS), and **Jalpaite** (?) (Ag_3CuS_2)

All five of these copper sulfides contain silver at the Sweet Home mine, and were probably the major source of silver for the mining operations from 1872 to 1966, although the early miners may have thought it was coming from the "argentiferous" galena (see Patton and others, 1912) associated with these sulfides (Figs. 201, 206). Stromeyerite is sparse, but where present it is a major silver mineral (Table 13), and would have contributed significantly to the Ag ore. Four analyses were made of a Ag-rich copper sulfide that is very fine-grained (2 microns); the electron microprobe results for all 4 analyses give low totals, which was probably a result of the very small size of the grains and the mineral's slightly oxidized nature. The stoichiometry of this phase is not clear

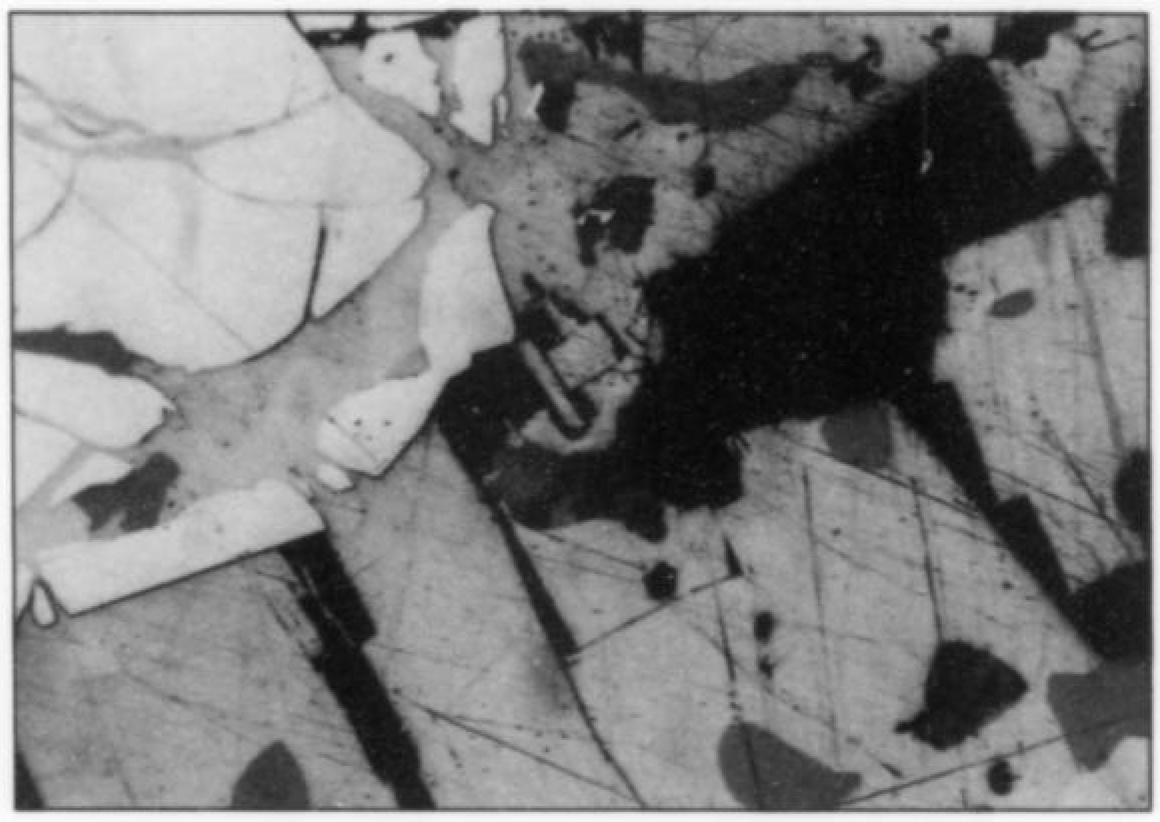


Figure 206. **Reflected-light photomicrograph of pyrite (yellow), chalcopyrite (gold), galena (gray), digenite (blue-gray), bornite (maroon), stromeyerite (purplish pink—small grain located in the center of the photo). Sample from the Main Stope. Horizontal field of view is 0.24 mm. Photograph by Karen Wenrich.**

Table 13. **Electron microprobe analyses of the silver-rich copper sulfides, bornite, digenite, spionkopite, stromeyerite, jalpaite(?). All of the analyses labeled as S105 were made within the area of Figure 209. Al, As, Ca, Cd, Co, K, Mg, Mo, Mn, Ni, P, Se, Si, Ti, V, and W were determined in all analyses, but were <0.3% (most are <0.1%). Values are in weight percent.**

Sample Number	*Cu*	*Ag*	*Fe*	*Zn*	*Pb*	*Ba*	*Hg*	*Sb*	*S*	*Total*
Bornite—Good Luck Pocket (2-B-L94 spot X1)	58.5	1.6	12.9	0.09	<.01	0.17	0.41	<.01	25.9	99.7
Bornite—Main Stope (S105 spot A2)	55.9	5.2	10.7	0.05	<.01	0.24	0.43	<.01	24.5	97.1
Digenite—Empty Pocket (FI-2 spot A1)	75.3	0.2	3.3	0.04	<.01	0.14	0.65	0.10	22.1	101.9
Jalpaite (?)—Museum Pocket (6-A-L94 spot A14*)	9.8	65.7	0.2	<.01	0.06	<.01	—	<.01	8.4	86.6
Jalpaite (?)—Museum Pocket (6-A-L94 spot A16*)	9.9	65.2	0.2	<.01	<.01	0.12	—	0.12	8.5	87.0
Spionkopite—Main Stope (S105 spot A10)	46.4	23.6	5.4	0.04	0.21	0.21	0.16	<.01	24.0	100.1
Spionkopite—Main Stope (S105 spot A4)	47.6	25.1	1.1	0.02	0.14	0.11	<.01	0.03	24.5	98.7
Stromeyerite—Main Stope (S105 spot A5)	29.8	50.7	0.01	0.04	<.01	0.22	4.13	<.01	16.1	101.1
Stromeyerite—Main Stope (S105 spot A6)	33.6	52.0	0.09	0.10	<.01	<.01	0.49	<.01	19.1	105.5

*Jalpaite (?): This mineral identification is very tenuous. The analysis is suspect because of the low totals. However, the approximate proportion of silver to copper should be reasonably accurate. The silver to copper ratio is roughly 3:1. The mineral is partially oxidized—the samples contain 1.56% and 1.98% oxygen respectively, and the totals are very low indicating an unreliable analysis. Such oxygen concentrations calculate to about 8.5 atomic percent oxygen. Both samples also contain Al: 0.53% and 0.71% respectively.

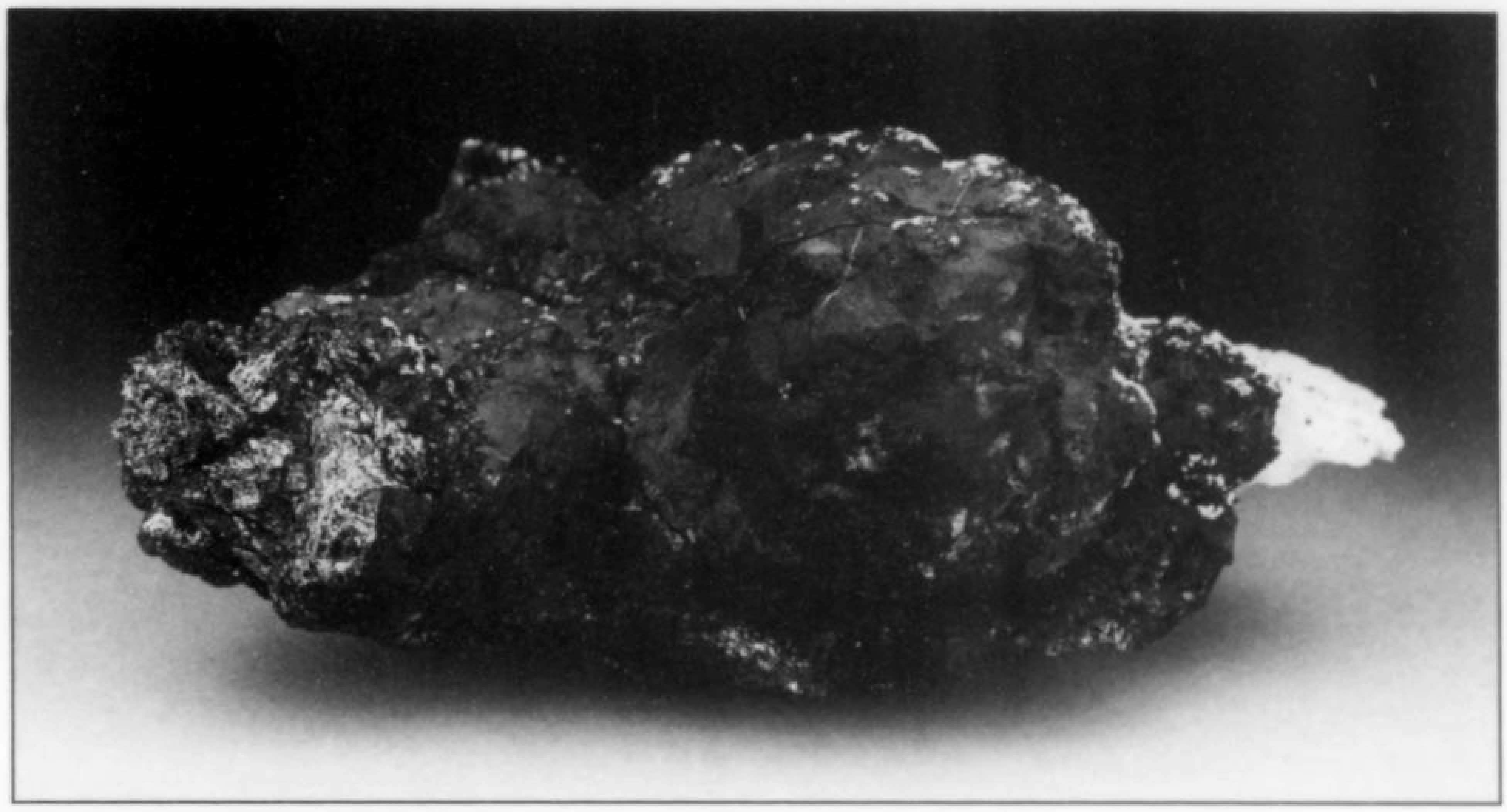


Figure 207. **Bornite associated with chalcopyrite and pyrite from the Tetrahedrite Pocket. This is the environment in which fine-grained digenite and spionkopite formed. Crystal group is 7.6 cm in length. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

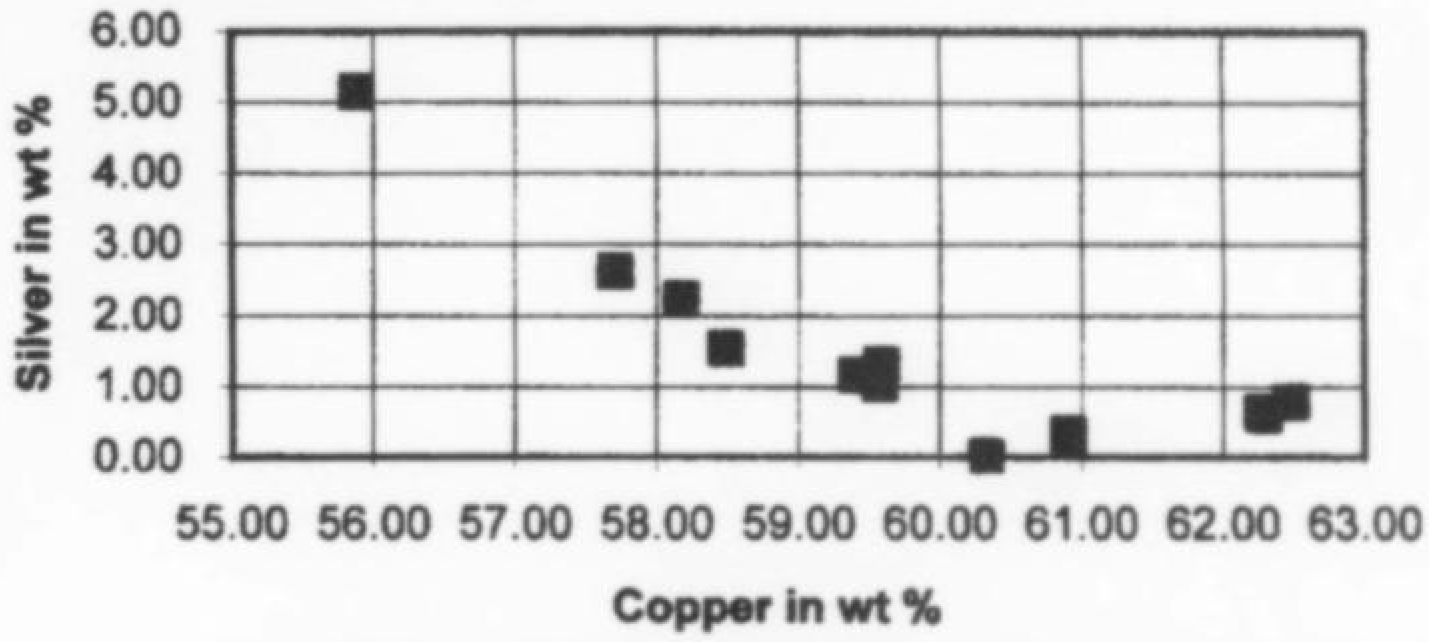


Figure 208. (right) **Silver versus copper in weight percent for bornite. Note the direct correlation between silver and copper, which suggests that the silver is substituting for copper in the crystal structure.**

because of the poor totals and partial oxidation, but it is not stromeyerite. It has tentatively been identified as jalpaite (?)—Ag_3CuS_2—(Table 13), but the stoichiometry works out to an oxidized jalpaite (?)—$Ag_{1.56}Cu_{0.41}S_{1.36}O_{0.62}$.

A bluish copper sulfide that petrographically used to be called *blaubleibender covellite* was described in 1980 as *spionkopite* ($Cu_{39}S_{28}$). Covellite was identified petrographically by Honea (1992). A bluish mineral from the Main Stope that appeared to be covellite was observed petrographically during this study. However, this "covellite" was analyzed on the microprobe (four analyses) and all results closely calculate stoichiometrically to $(Cu,Ag,Fe)_{39}S_{28}$. They are therefore referred to here as spionkopite (Table 13). They contain significant amounts of silver, 23–38 weight %. More research needs to be done on this Sweet Home species. It is possible that X-ray diffraction studies might identify it as a new species rather than merely spionkopite with Ag substituting into the Cu site.

No native silver was observed during these petrographic and electron microprobe studies. All of these copper sulfides have anomalous Hg concentrations, which in one case is over 4 weight %. None of these copper sulfides are as common at the Sweet Home as sulfides such as pyrite, galena, sphalerite or chalcopyrite. However, some nice samples have been discovered in the mine (Fig. 207).

A graph of silver versus copper in bornite (Fig. 208) illustrates a direct correlation between the two elements, indicating that silver has substituted for copper in the crystal lattice. These copper sulfides are late in the paragenetic sequence and have apparently replaced earlier sulfides. Locally they fill skeletal tetrahedrite crystals, and as shown in Fig. 209, wormy galena can be observed to lie within bornite that has partially replaced the galena.

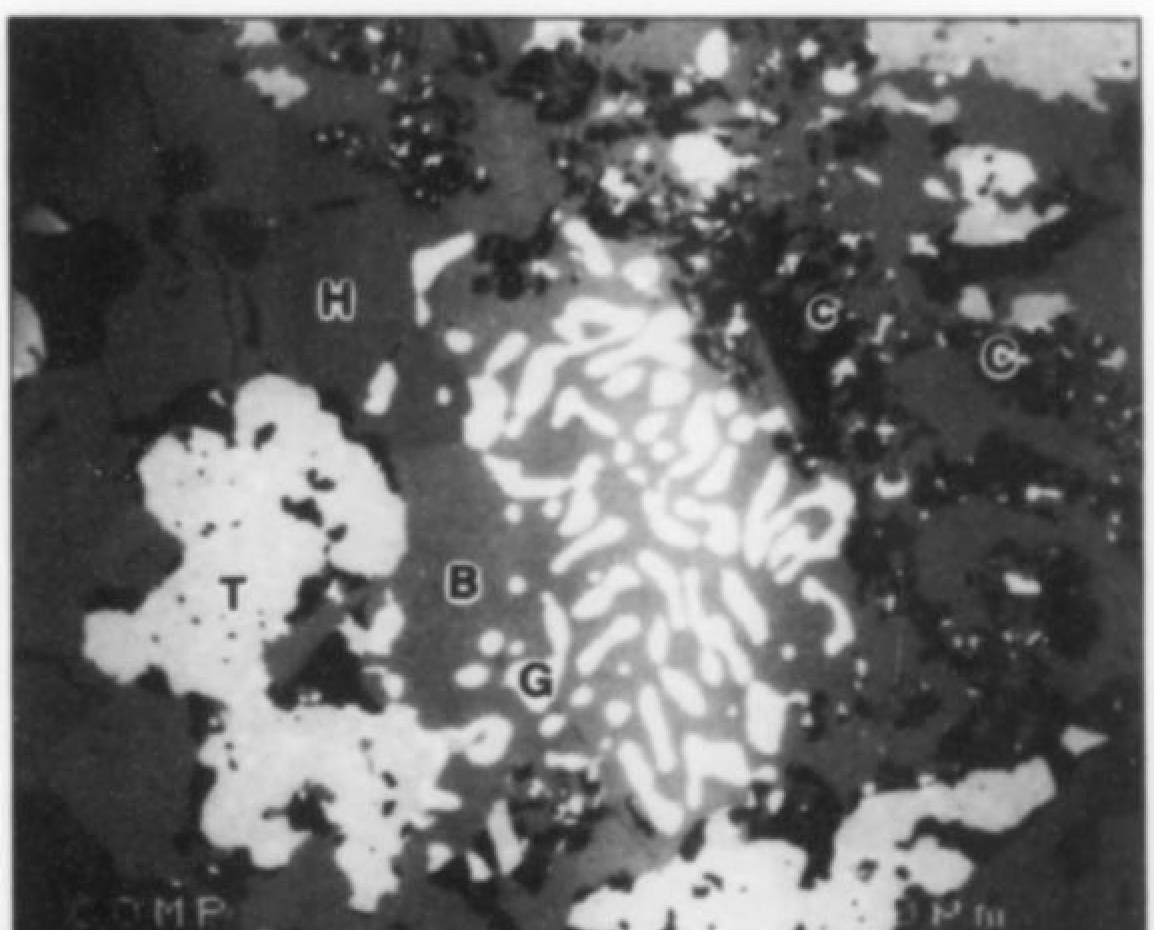
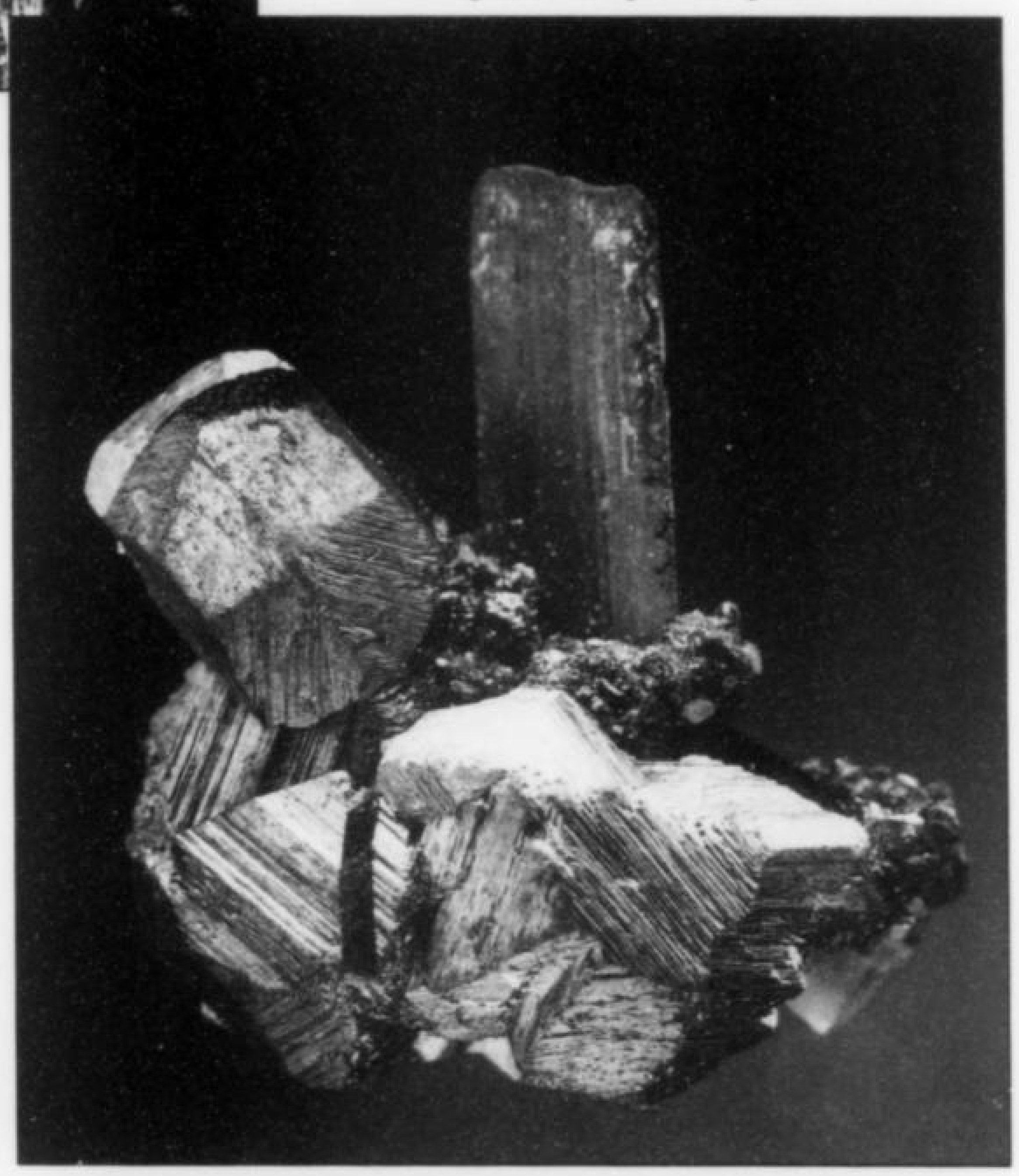


Figure 209. **Electron backscatter image of sulfides from the Museum Pocket. "Wormy" galena (G) is enclosed by bornite (B). Small irregular grains of chalcopyrite (C) lie associated with the black gangue. Tetrahedrite (T) grains appear somewhat spongy as though they, like the galena, were undergoing alteration from the copper-bearing fluids precipitating the late-stage bornite. Sphalerite (H), like the bornite, surrounds some of the "wormy" galena. Length of galena "worms" is about 100 microns. Photograph by Karen Wenrich.**

Figure 210. **Blades of hübnerite associated with smaller quartz crystals from the Hübnerite Pocket. Note the gemmy orange color revealed along the thin edges of the blades. Horizontal field of view is 5 cm. Sweet Home Rhodo, Inc. collection; photo by Jeff Scovil.**

Figure 211. (below) **Large single blade of hübnerite associated with chalcopyrite from the Rainbow Pocket, 2.5 cm. Dave Bunk specimen; photo by Jeff Scovil.**



OXIDES, FLUORIDES, and PHOSPHATES

Hübnerite $MnWO_4$

Hübnerite from the Sweet Home mine is very close in composition to the pure end-member of the hübnerite-ferberite solid solution series, so much so that in thin section the color is a gemmy orange. This orange translucent color is visible along the thin edges of large hübnerite blades (Fig. 210). When a thin slice of the crystal is cut and the slice is viewed in transmitted light under a microscope, distinct compositional banding is obvious (Fig. 212). The gemmy orange bands are essentially pure $MnWO_4$. Only a very small amount of iron (around 0.35 weight %) substituting for the Mn is required to turn the orange hübnerite black. The hübnerite in several samples is associated with muscovite (Fig. 213), and also with chalcopyrite (Fig. 211).

Figure 212. **Transmitted plane light photomicrograph of a single gemmy orange hübnerite blade from the Coors Pocket. Note the compositional banding. Gemmy orange bands are essentially pure $MnWO_4$. Only a very small amount of iron (<0.35 wt. %) substituting for the Mn is required to turn the orange hübnerite into the black bands. Horizontal field of view is 1.05 mm. Photograph by Karen Wenrich.**

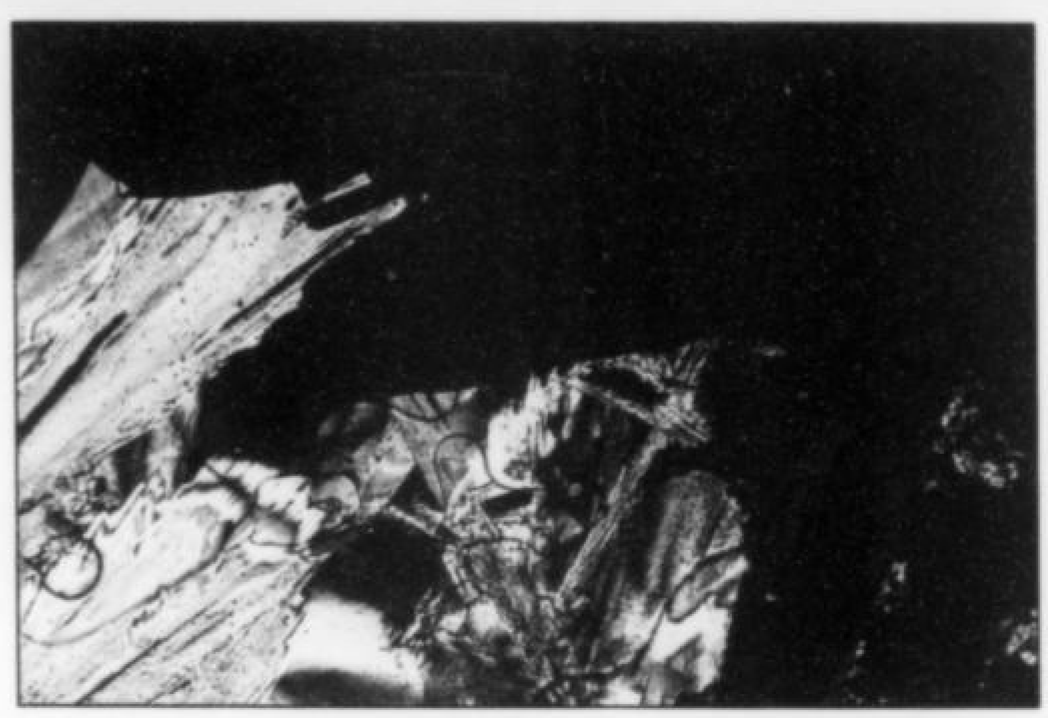


Figure 213. **Transmitted-light photomicrograph with crossed nicols of hübnerite (orange) associated with radiating aggregates of muscovite (pastel shades) from the Coors Pocket. Horizontal field of view is 2.1 mm. Photograph by Karen Wenrich.**

Table 14. **Electron microprobe analyses of fluorapatite and triplite. All values are in weight percent. Al, Ag, As, Ba, Cd, Co, Hg, K, Mo, Ni, Pb, Se, Si, Ti, V, W, and An were determined in all analyses, but were <0.12% (most are <0.04%).**

Sample Number	*Mn*	*Mg*	*Fe*	*Ca*	*P*	*O*	*F*	*Total*
Fluorapatite—Empty Pocket (9-A-L94 spot X3)	2.2	<.01	0.01	37.2	17.2	37.5	4.5	99.0
Fluorapatite—Red & Blue Pocket (10-A-L94 spot X2)	0.9	<.01	<.01	38.3	17.1	39.1	3.3	99.2
Triplite—Empty Pocket (9-A-L94 spot A9)	44.5	1.0	0.2	1.7	13.9	31.6	5.2	98.3
Triplite—Empty Pocket (9-A-L94 spot A11)	46.3	0.5	0.2	2.0	14.0	31.8	4.0	99.1

Table 15. **Electron microprobe analyses of muscovite—23 analyses were made of this mineral from various pockets in the Sweet Home mine. The results are not as accurate as the other minerals analyzed in this report because fluorine and oxygen are difficult elements to determine and more time and standardization was necessary for high accuracy results. Many more elements were enriched in the muscovite than in the sulfides. For example concentrations of Ti and Ba are generally between 0.03 and 0.15%. Values are in weight percent.**

Sample Number	*Si*	*Al*	*K*	*Mn*	*Fe*	*Mg*	*O*	*F*	*Total*
Watercourse Drift (8-A-L94 spot X8)	23.7	18.0	1.6	1.8	0.1	0.4	47.5	4.2	99.6
Red & Blue Pocket (10-A-L94 spot A17)	22.6	19.2	2.3	0.3	0.6	0.6	48.4	4.0	98.4

Fluorite CaF_2

Fluorite formed during two distinct and separate stages: (1) an early green fluorite, and (2) a later purple fluorite. Electron microprobe analyses of the fluorite indicate that these minerals are very pure and stoichiometric. As is normally the case, the color in fluorite is not due to any detectable changes in trace element impurities. The late-stage purple fluorite is wispy in places, but microprobe analyses do not show any compositional variations between the purple wisps and the colorless wisps in between. This is not surprising because the color in fluorite has generally been attributed to physical properties other than compositional variation. However, extensive studies have been done on the color in fluorite and some colors are believed to be attributable to trace concentrations of rare earth elements, concentration levels well below the lower detection limit of these elements on the electron microprobe.

Fluorapatite $Ca_5(PO_4)_3F$

Elongated doubly terminated apatite grains have been found as inclusions within the rhodochrosite in samples from both the Empty and Red & Blue pockets. Electron microprobe analyses of these apatites indicate that they are fluorapatite (Table 14).

Triplite $(Mn,Fe,Mg,Ca)_2(PO_4)(F,OH)$

Three grains of triplite occur as small inclusions (about 20 microns each) in fluorapatite that rims a large rhodochrosite crystal from the Empty Pocket. The electron microprobe analyses of the triplite are very stoichiometric considering the size of the grains that were analyzed (Table 14).

SILICATES

Muscovite $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Muscovite books are not uncommon in the Sweet Home mine. Electron microprobe analyses were made of muscovite from the Corner Pocket, Coors Pocket, Watercourse Drift, and the Red and Blue Pocket (Table 15). The most common occurrence of the muscovite is in radiating aggregates in association with hübnerite (Fig. 213).

Topaz $Al_2SiO_4(F,OH)_2$

Topaz inclusions are very common in the quartz crystals associated with rhodochrosite, fluorite, sphalerite, and tetrahedrite/tennantite. Although much of the quartz contains no such inclusions, the quartz that does contains a lot of topaz inclusions. Electron microprobe analyses of two topaz crystals indicate that the mineral is stoichiometric and has almost no detectable trace elements.

Quartz SiO_2

Quartz is the earliest formed mineral in the Sweet Home mine suite, and forms well-developed terminated crystals onto which many of the subsequent minerals have grown. Large quartz crystals are commonly surrounded by sulfides, particularly tetrahedrite, chalcopyrite and sphalerite.

Dickite $Al_2Si_2O_5(OH)_4$

Very fine-grained clusters of greenish crystals of dickite were found and analyzed on the electron microprobe (Table 16).

Table 16. **Electron microprobe analyses of dickite. All values are in weight percent. Ag, As, Ba, Ca, Cd, Co, Cu, Mo, Ni, P, Pb, S, Se, Si, Ti, V, W, and An were determined in all analyses, but were <0.06% (most are <0.02%).**

Sample Number	*Mn*	*Mg*	*Fe*	*K*	*Si*	*Al*	*F*	*O*	*Total*
Dickite—Coors Pocket (5-C-L94 spot X12)	0.23	0.94	0.15	8.4	22.6	17.7	2.0	47.8	100.3
Dickite—Pyrite Pocket (7-A-L94 spot X9)	0.52	0.94	0.21	8.1	24.5	15.7	3.1	46.9	101.1

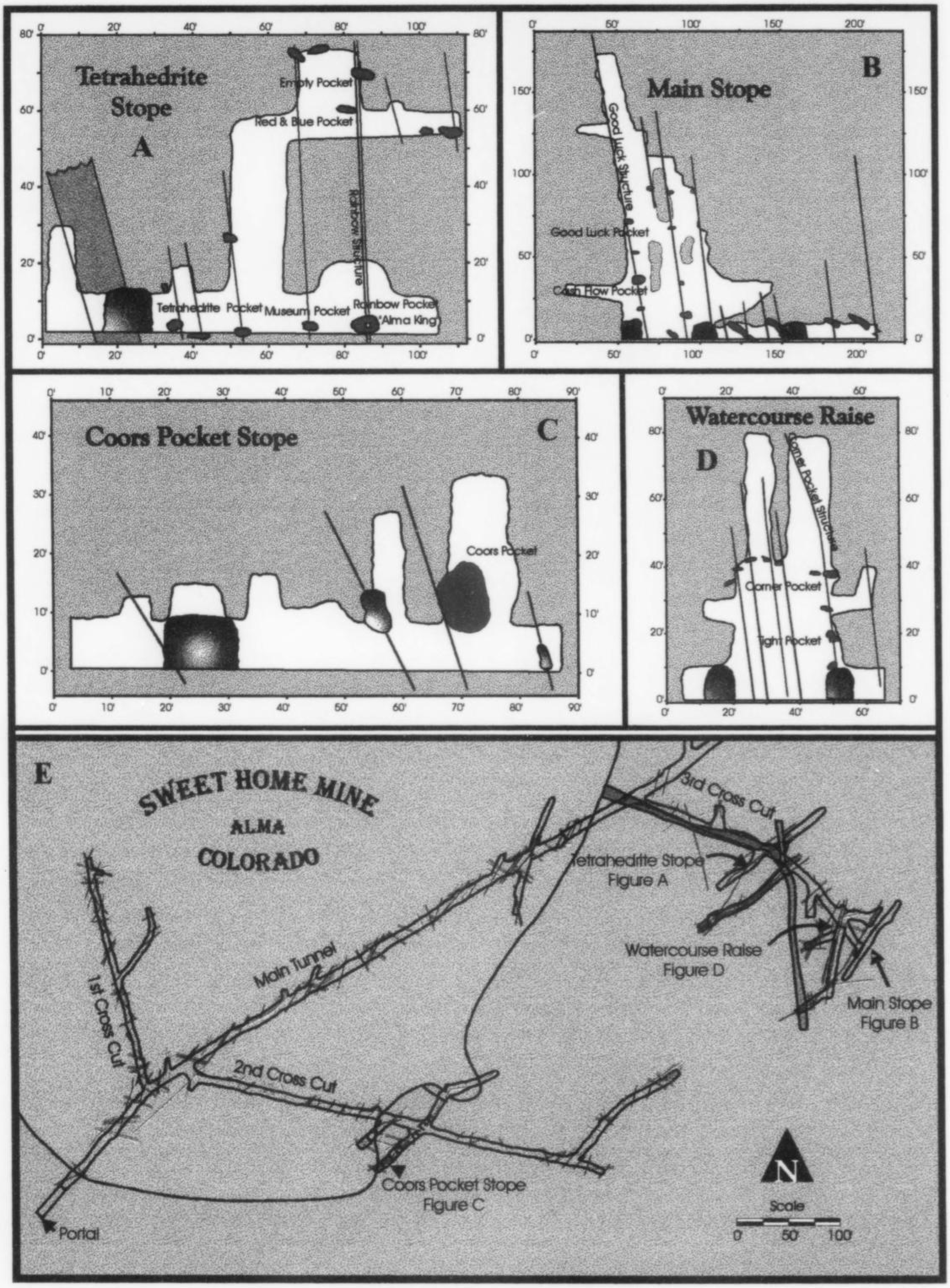


Figure 214. **Mine location map for the stopes and pockets discussed in this article. The Main Stope (in contrast to the Tetrahedrite Stope, Watercourse Raise, and Coors Pocket) has higher arsenic tetrahedrite/tennantite and lower Fe+Ca+Mg rhodochrosite.**

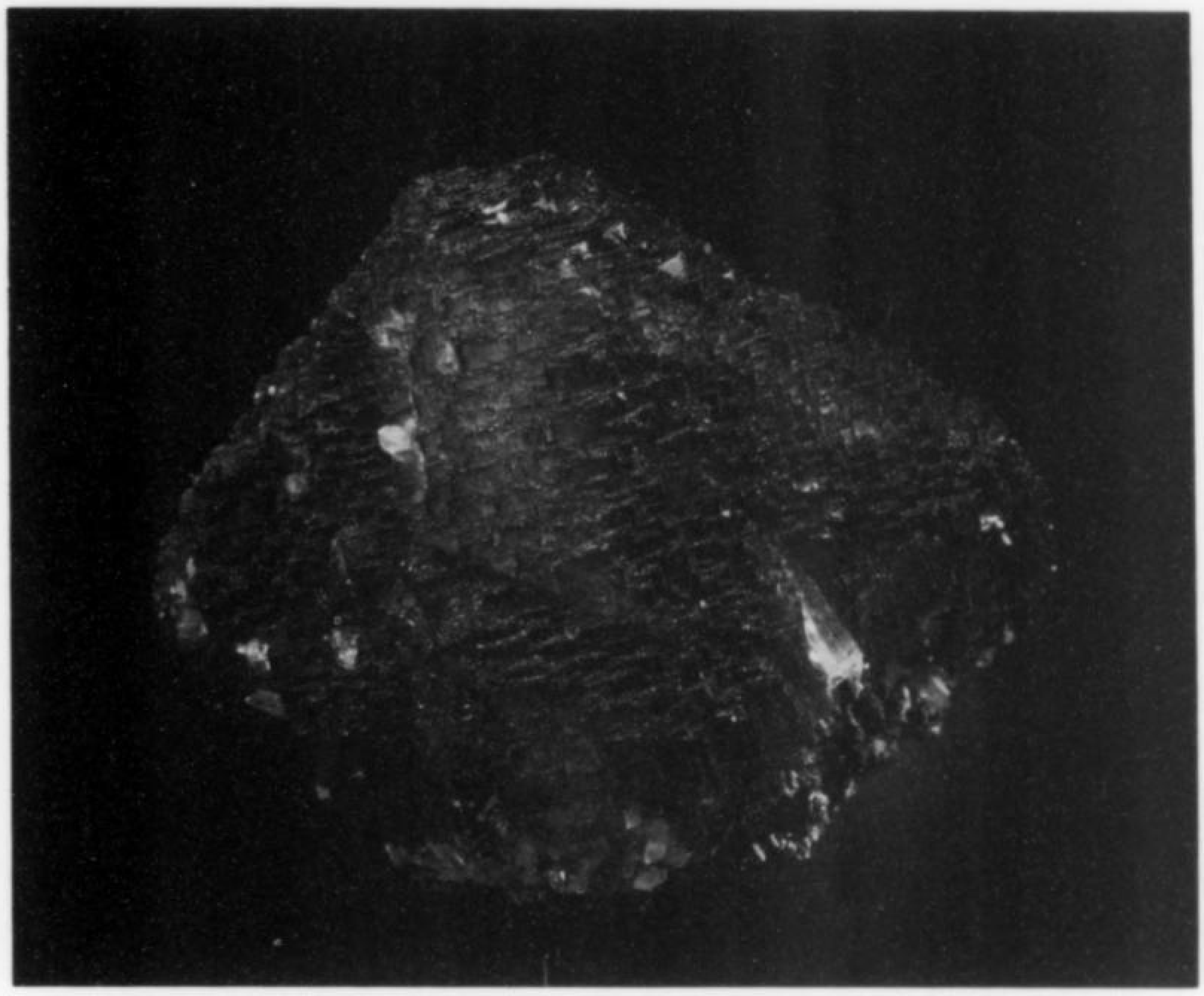


Figure 215. **Fluorite, Blueberry Pocket, 4.5 cm, found through ground-penetrating radar (GPR) exploration work. Photo by Jeffrey Scovil.**

CRYSTAL CHEMICAL ZONING

Most minerals in the Sweet Home mine are relatively pure stoichiometric end-members. However, tetrahedrite/tennantite and rhodochrosite are not. Tetrahedrite/tennantite spans most of the solid solution series between the two end members (see Fig. 199). Although rhodochrosite does not have such extensive solid solution, the content of Fe+Ca+Mg does substitute so significantly for Mn that the color of rhodochrosite is dramatically altered (see chapter on color in rhodochrosite, this issue). Likewise, sphalerite shows very minor enrichment in Fe.

Coincidentally the "contamination" of rhodochrosite, tetrahedrite and sphalerite generally occur within the same areas of the Sweet Home mine. High-antimony tetrahedrite/tennantite, higher-Fe+Ca+Mg rhodochrosite, and higher-iron sphalerite all occur in the Tetrahedrite Stope whereas the Main Stope is just the opposite (Figs. 214A, 214B). The Coors Pocket (Fig. 214C) and the Watercourse Raise (Fig. 214D) contain some low and some moderate trace-element substitution in their crystals.

Higher As tetrahedrite/tennantite and low Fe sphalerite correlate nicely with the areas of the highest quality, gemmy cherry-red rhodochrosite: the best comes from the Main Stope (Fig. 214B), and if these four areas are ranked the Tetrahedrite Stope is fourth in quality.

CONCLUSIONS

The electron microprobe has provided quantitative chemical analyses of most mineral phases known to be present in the Sweet Home mine, including some that are only 2–3 microns in size. Owners of Sweet Home sulfide specimens can feel more confident in the labels put on their specimens than is often possible from other mines where no specimens have been chemically analyzed. Overall the samples analyzed during this study indicate that there is twice as much tetrahedrite as tennantite, and that the two phases are intricately intergrown in many samples.

In addition to clarifying the chemistry of Sweet Home minerals the microprobe has been instrumental in determining the amount of trace elements contaminating certain mineral species found in conjunction with rhodochrosite. In particular, analyses have shown that iron substitution in sphalerite and high antimony in tennantite/tetrahedrite correlate well with the Fe+Ca+Mg substitution in the low-temperature rhodochrosite (see section on color in rhodochrosite, Fig. 187, this issue). Analyzed veins and pockets that show elevated iron contamination in the sphalerite, and high antimony-to-arsenic ratios in the tetrahedrite/tennantite (toward the tetrahedrite end-member), match up with the same veins and pockets that contain Fe+Ca+Mg contamination in the rhodochrosite. Areas which contain such trace-element contamination of sphalerite, tetrahedrite and rhodochrosite have historically produced lower-quality rhodochrosite.

The mining company now uses this information as an exploration tool. When a sulfide vein is encountered, and contains no visible rhodochrosite, its sphalerite and tetrahedrite can be analyzed for iron and antimony, respectively. If elevated levels of these elements are found, that vein will not be a primary target and may be avoided completely. If the tetrahedrite and sphalerite have the proper chemistry, then the vein may offer a favorable exploration target.

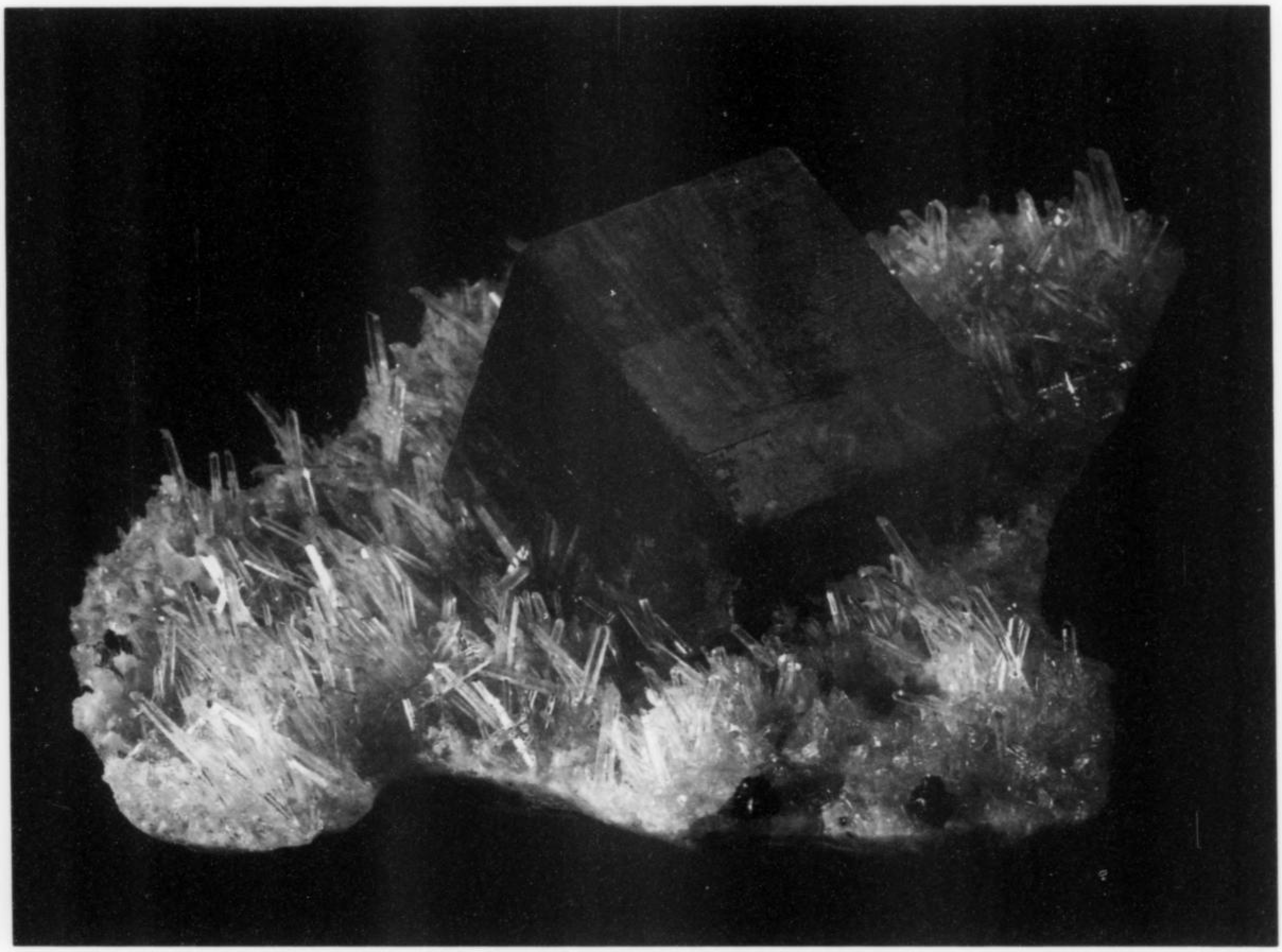


Figure 216. **Rhodochrosite on quartz, 10.4 cm, from the Blueberry Pocket, found through GPR exploration work. Photo by Jeffrey Scovil.**

The Application of Ground-Penetrating Radar to Mineral Specimen Mining

Bryan K. Lees
P.O. Box 1169
Golden, Colorado 80402

INTRODUCTION

In the summers of 1993 and 1994, a new approach to explore for crystal cavities was tested: it involved the use of ground-penetrating radar, or GPR for short. GPR is similar in many respects to sonar and seismic methods, and is typically used to detect near-surface objects such as buried oil drums, subsidence features and unstable ground in coal mines.

Typical penetration depths for GPR systems range from just a few inches to up to 100 feet. The resolutions of these systems vary with the antenna size, but features as small as 12 inches are detectable. Larger features are more readily discernible, especially those measuring 5 feet or more in diameter. The Sweet Home GPR survey, although unconventional, was an ideal test for this type of geophysical technique because crystal cavities typically measure in the 1 to 5-foot range and are usually discovered within 20 feet of the "surface." The GPR surveys, done underground at the Sweet Home mine, examined tunnel walls with hopes of being able to "see" into the rock 20 to 30 feet.

BACKGROUND

Ground Penetrating Radar has been around for several decades; it is not a new technology. Early variations of GPR were used for locating enemy tunnels during the Vietnam War. These early systems were slow, complicated and not very field-worthy. What has suddenly made GPR so usable is the development of portable high-speed personal computers and better interpretive software programs. The new PCs are capable of handling the volumes of complex data generated by the GPR systems and processing them in the field immediately. Users can literally see the results of ground scans as fast as they can do them.

Today, GPR's use has expanded into many applications including locating buried drums for environmental cleanups, discovering buried cables, delineating bad ground in coal mines, locating hidden karst topography in Florida, and mapping old underground mine tunnels, to mention a few. In the field of mineral collecting, it was only a matter of time before this new technology was tried. It is a field collector's dream to be able to "see" into the rock being prospected for crystal cavities. As little as 10 years ago, this type of technology was unavailable.

ELECTROMAGNETIC THEORY AND GPR

Volumes have been written about electromagnetic theory and its application to GPR; most of it is beyond the scope of this article. The paragraphs below cover some very basic electromagnetic principles as they apply to GPR use. For further research into electromagnetic theory and its application to GPR, the reader is referred to Davis and Annan, 1989; Fisher *et al.*, 1992; Reitz and Milford, 1962; Scaife and Annan, 1991; and Telford *et al.*, 1976.

A typical GPR system consists of a computer, radar box, printer/plotter, car battery and one or two antenna(e). The system is used by pulling the antenna along the ground while the other components remain stationary. The antennae are attached to the radar system by fiber optic cable.

Radar Pulses

The radar produces short-duration pulses of high-frequency electromagnetic energy. Typical frequencies range from 10 to 900 Mhz. This energy is transferred into the ground through the antenna array in a cone-shaped beam. The energy is reflected by features within the ground and returned to the system as signals (Fig. 218). These signals are amplified by the receiver, digitized and stored in the computer. The digitized information can be seen in real-time or can be stored for post-survey processing.

Penetration Depth

Penetration depths vary with the electrical conductivity of the ground material. As electrical conductivity increases, the radar signal is dissipated as heat into the ground. Materials with high conductivity can limit penetration depths to a few feet. For instance, sand and granite have conductivities in the range of 0.01 mS/m (milliSiemens per meter) and can be scanned to depths of over 50 feet. Air has a

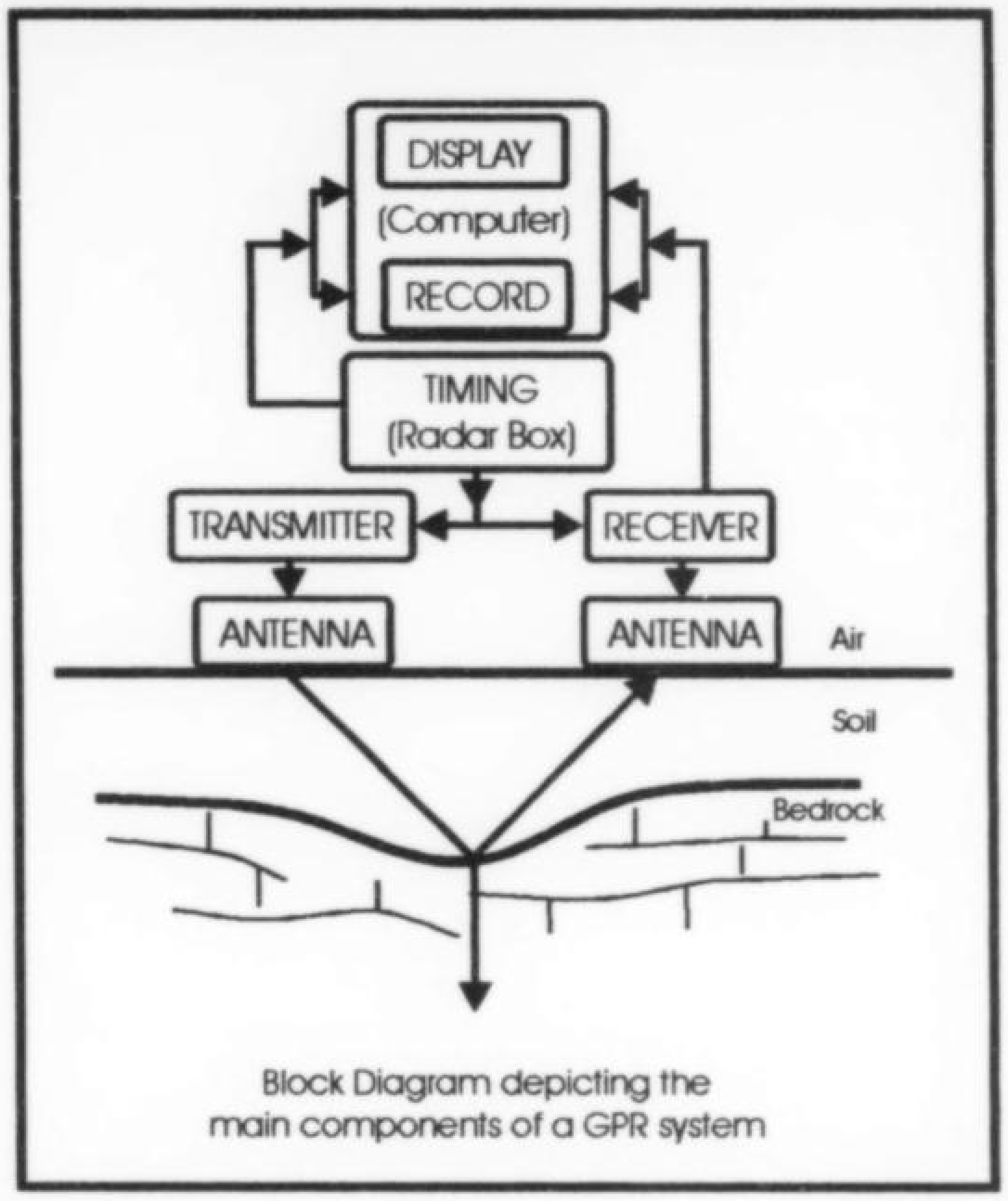


Figure 217. (above) **Block diagram depicting the main components of a GPR system.**

conductivity of 0 mS/m. Clay and sea water, however, have conductivities in the range of 1000 to 3000 mS/m and dramatically limit signal penetration down to a few feet. High-conductivity materials are not good mediums for GPR use. However, regardless of conductivity, after a certain distance, the GPR signal dies out anyway through absorption by the rock and is converted into heat. As the signal dies out, a maximum penetration depth is achieved. Each GPR application's penetration depth is dependent on the ground's conductivity, and hence, the composition of the host rock.

Relative target depths are determined by measuring the time it takes for the electromagnetic pulses, typically lasting 2 to 5 nanoseconds, to penetrate the rock strata and then return to the receiving antenna. Differences in rock type create differences in signal velocities and return times. Once the velocity of the target rock is calculated, the timing of the return signals can be calibrated and transformed into depth measurements. For example, if a particular signal takes 100 nanoseconds to return to the system and this corresponds to rock penetration of 15 feet, then, a signal returning in 200 nanoseconds may correspond to a rock depth of 30 feet, and so on.

Dielectric Variability

Another important component of electromagnetic wave propagation through earth materials is the ground's dielectric constant.

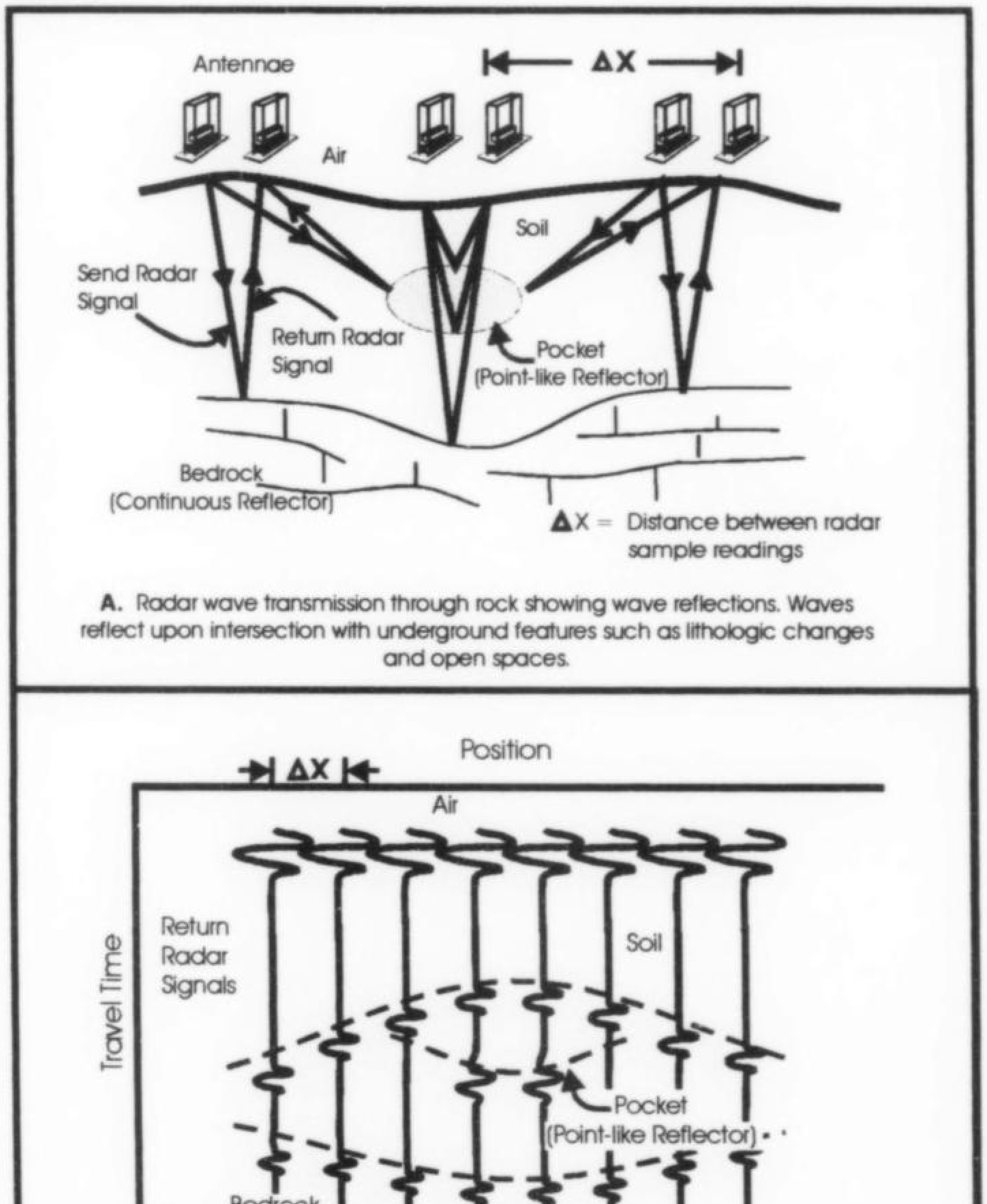


Figure 218. (right) **Radar wave transmission through rock showing wave reflections.**

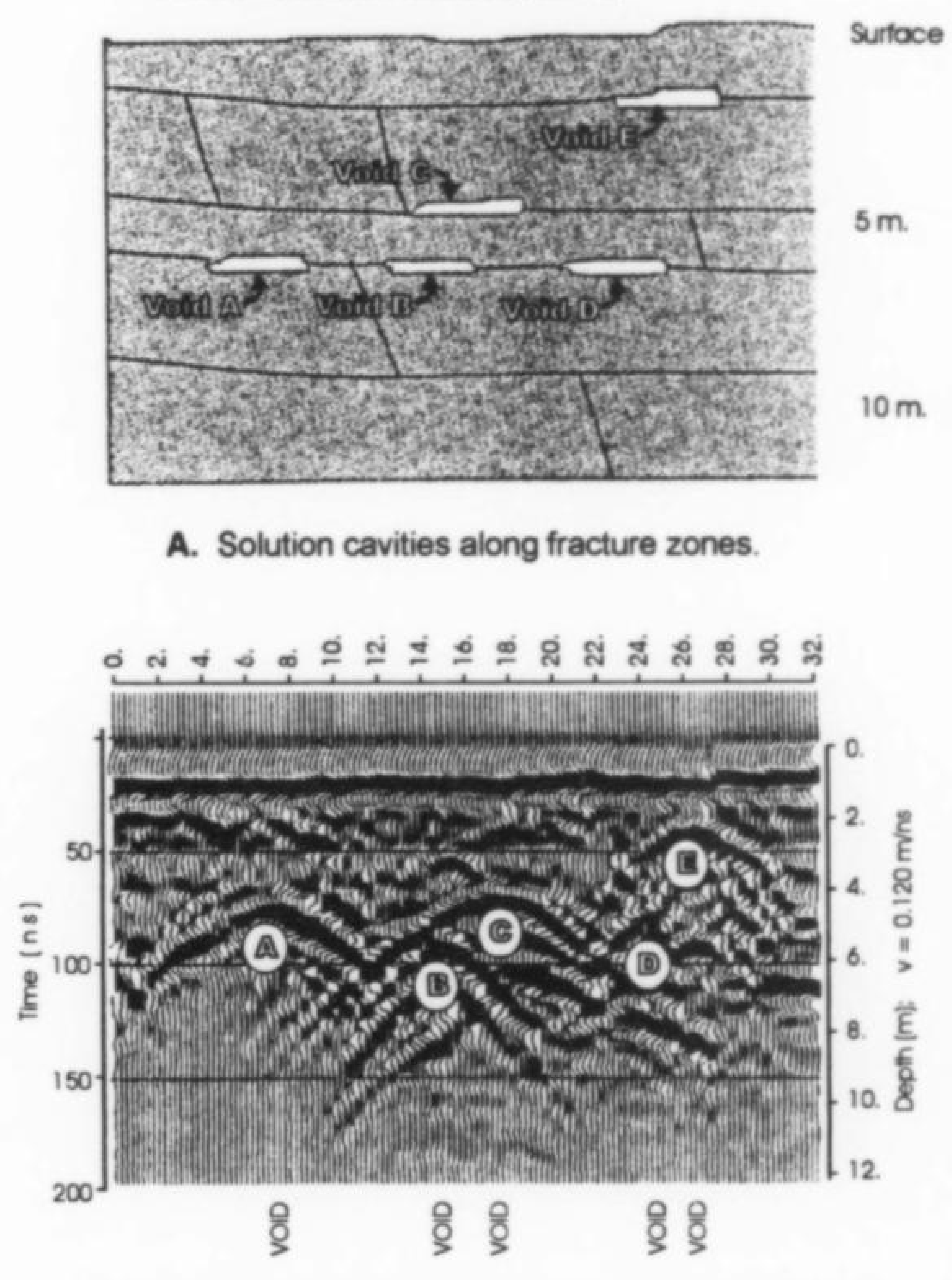
When an electrical field is applied to a material it is stored (in the material) as energy. When the field is turned off, the material dissipates that charge and returns to its earlier state. This is what happens when energy in the form of radar waves is applied to the ground by the GPR system. Each material reacts to flows of electrical current in a different manner. This ability of a material to store and release electromagnetic energy is measured by its dielectric constant, and each earth material has a unique constant: K. The constants for air, water, granite and clay are 1, 80, 6 and 5-40 respectively. As GPR waves propagate downward, signal reflections are generated by changes in dielectric constants as the radar waves interact with different compositions of ground materials and void spaces. The changes in dielectric constants create reflections which show up on the printouts as wavy lines.

To summarize, different earth materials can be delineated with GPR by their contrast in electrical properties, particularly conductivity and dielectric constant. The GPR system's emission signals are altered by these properties as they propagate through earth materials. The altered signals are reflected back to the system after a few nanoseconds where they are processed and stored in the computer. The geophysicist analyzes the printouts looking for signs of faults, lithologic changes, buried objects and crystal cavities.

Cavity Detection

Figure 219 illustrates a situation showing how voids create reflections which show up on GPR printouts. This illustration is not taken from the Sweet Home mine, but from a hypothetical limestone karst in Florida. The limestone is homogenous and contains small cavities—ideal conditions for the use of GPR. The signals easily detect the voids as the electrical properties change between the air pockets and limestone. The reflected signals produce a series of hyperbolic-looking hillocks on the GPR system's printer (or screen), thus signaling the presence of a void. This is a common example of GPR's use for cavity detection. Unfortunately, not all applications are quite as simple as this one. Variables such as changing lithologies, fractures, water, interbedded clay and materials mixed with heavy mineral content all influence the electrical properties of the host rock, and thus complicate interpretation. These properties all played an important part in the GPR results and the data interpretation of the Sweet Home mine GPR survey.

***Figure 219.* Void detection in limestone rock using GPR system. (After MultiView Geoservices Inc. manual, 1994.)**



B. GPR data trace showing detection of solution cavities.

Finally, it should be mentioned that not all of the factors influencing electromagnetic wave propagation and their relationship to GPR have been covered in this article. The interested reader should look up the cited references for further, and more advanced, reading.

SYSTEM TYPES AND FEATURES

When looking for crystal cavities, one would like to know their approximate size and orientation. The reason for this is that void size is inversely proportional to the radar frequency used to find it.

For example, a 50 MHz antenna may penetrate up to 50 or 60 feet into the rock at the Sweet Home mine. Unfortunately, the 50 MHz antenna, while attaining deep penetration, does so at the expense of resolution. The 50 MHz antenna, in Sweet Home mine rock, will only "see" objects that are about 5 feet across and larger.

In contrast, the 100 MHz antenna may only "see" 25 feet into the Sweet Home mine rock but does so with minimal sacrifice in resolution. The 100 MHz antenna can discern objects down to 1 or 2 feet.

Resolution is an important factor at the Sweet Home mine because the average pocket size is about 1 to 2 feet. So, if the 50 MHz antenna is used, there is a risk of missing small but valuable rhodochrosite pockets. Thus, the 100 MHz antenna was employed throughout the radar survey.

Note also that radar frequency is inversely proportional to penetration depth. If one were looking for large targets (in the 5 to 10-foot range), one could use antennae with frequencies down to 10 MHz and possibly "see" upwards of 100 feet into certain types of rock. Therefore, if the potential targets are large enough, deeper penetration can significantly increase the odds of finding a pocket simply because one is scanning a large volume of material.

Using GPR systems underground is not easy. Many systems are engineered for surface work and are not protected against the rigors of underground use. Extremely wet or cold conditions make system use difficult.

At the Sweet Home mine, two different GPR systems were tried. The first tests were conducted using a Sensors and Software Inc. pulseEKKO IV(TM) system from Toronto, Canada. The second set of tests employed a Geophysical Survey Systems, Inc. SIR-3(TM) system from North Salem, New Hampshire. At the time of the tests, each system had some difficulties dealing with underground conditions. Moisture and cool temperatures were the biggest problems. System shutdowns occurred periodically; however, persistence paid off and each system performed well in the end. Since 1993, when the original test was conducted, several advances in GPR systems have made them more user-friendly and field-worthy. Field packs have better waterproofing and some systems come with built-in heaters to maintain proper operating temperatures.

SWEET HOME MINE GPR SURVEY

GPR surveys were made through the entire mine using several different types of antennae and scanning techniques. Since it was not known what to expect from the scans, several different setups were tried. After two days of scanning, the best results were obtained by using the 100 MHz antenna. This antenna, for reasons described above, worked best for locating the small voids that typically occur in the Sweet Home mine.

Depth penetration was a problem at the Sweet Home mine. Hindered by irregularities in the tunnel surfaces, the survey team was unable to make tight antenna-to-wall couplings. Too much air space between the antenna and wall meant that some of the radar signal could not make it into the tunnel wall; some of the radar energy was lost in the air space. This resulted in only a 20-foot penetration of the granite walls instead of the desired 50-foot depth. Still, 20 feet allowed a peek into the surrounding rock.

GPR detects changes in electrical properties of rock. Unfortunately, however, it does not interpret them. Data interpretation usually requires someone who is familiar with GPR readouts from similar applications. Up until 1993, few people had tried to use GPR for crystal cavity exploration; hence, there were no blueprints against which to check Sweet Home results. Basically, the mine staff drew new "blueprints" for Sweet Home GPR data. This involved careful comparison of the geologic maps to the GPR data followed by careful drill probing and tunnel development.

SWEET HOME MINE DATA INTERPRETATION

The mine area studied and GPR surveyed in detail was Crosscut No. 3. This area shows complex geology as well as interesting looking GPR traces.

Figure 220 shows the raw GPR data used in the third crosscut interpretation. Interpretation is difficult, but careful analysis of this GPR scan identified the proposed fractures and cavities shown in Figure 220b. The difficulties arise in noticing the subtle changes within the GPR data. After careful study, certain linear and hyperbolic features in the third crosscut scans became noticeable. The linear features in GPR data are called "continuous reflectors" (CR-l and CR-2, in the figure) and the hyperbolic features are called "point-like reflectors" (PR-l in the figure).

Linear features in the GPR data constitute a significant change in electrical properties from one area to another and account for things like faults and lithology changes. Point-like reflectors signify a small localized change in electrical properties such as open space or buried objects.

The host rock in the survey area is composed of Precambrian granite gneiss. The granite gneiss is intruded locally by Tertiary quartz monzonite porphyry dikes. Both rock units are crosscut by geologic features such as veins, faults and joints. Veins and faults may contain massive sulfide minerals, crystal cavities, clay, or just water.

The first feature discerned by the Sweet Home mine GPR survey was the existence of a quartz monzonite porphyry dike that had gone undetected during geologic mapping. This linear feature showed up as a continuous reflector (marked CR-l in Figures 220 and 221) in the 3rd crosscut scan. Upon visual examination of the 3rd crosscut tunnel wall, the dike was found, thus proving the system's capabilities to see changes in lithology.

To complete the interpretation of the Sweet Home mine scans, GPR printouts were made to the same scale as the mine maps. Then, the GPR printouts were overlain onto the mine maps (Fig. 221). This produced some interesting results. First, a linear feature observed in the GPR data (marked CR-3 in Fig. 221) lined up with known faults (thin blue lines in Fig. 221) mapped a year earlier by Sweet Home geologists along the 3rd crosscut tunnel wall.

Next, upon further examination of the GPR traces, geologists discerned additional linear features within the GPR data (CR-2 in Figs. 220 and 221) that suggested the existence of faults that were missed while doing the original mine mapping. Later, upon careful examination of the third crosscut tunnel walls, these small faults were detected. These same faults, when extrapolated eastward, correlated with the same structures which created the Good Luck Pocket in the Main Stope.

When the GPR interpretation was completed, it became obvious that there were several places inside the tunnel wall where fault intersections occurred (see intersection of CR-2 with CR-3). Some of these were within 20 feet of the 3rd crosscut tunnel wall. Past mining experience at the Sweet Home mine had already demonstrated that pockets occur at fault intersections.

In addition to locating and extrapolating faults, examination of the 3rd crosscut GPR data revealed a series of hyperbolic features suggestive of open cavities, or potential crystal cavity zones (PR-l, Figs. 220 and 221). These hyperbolic features coincided with the fault intersection areas. The geologists now had an additional piece of information to increase their confidence level that this was a good pocket target area.

To test the interpretation of the Sweet Home mine GPR data, a short exploration tunnel was driven into the area thought most likely to produce crystal pockets. The exploration tunnel followed a fault (which coincided with CR-3 in Fig. 221) and intersected two pockets in the areas suggested by the GPR survey (see Fig.

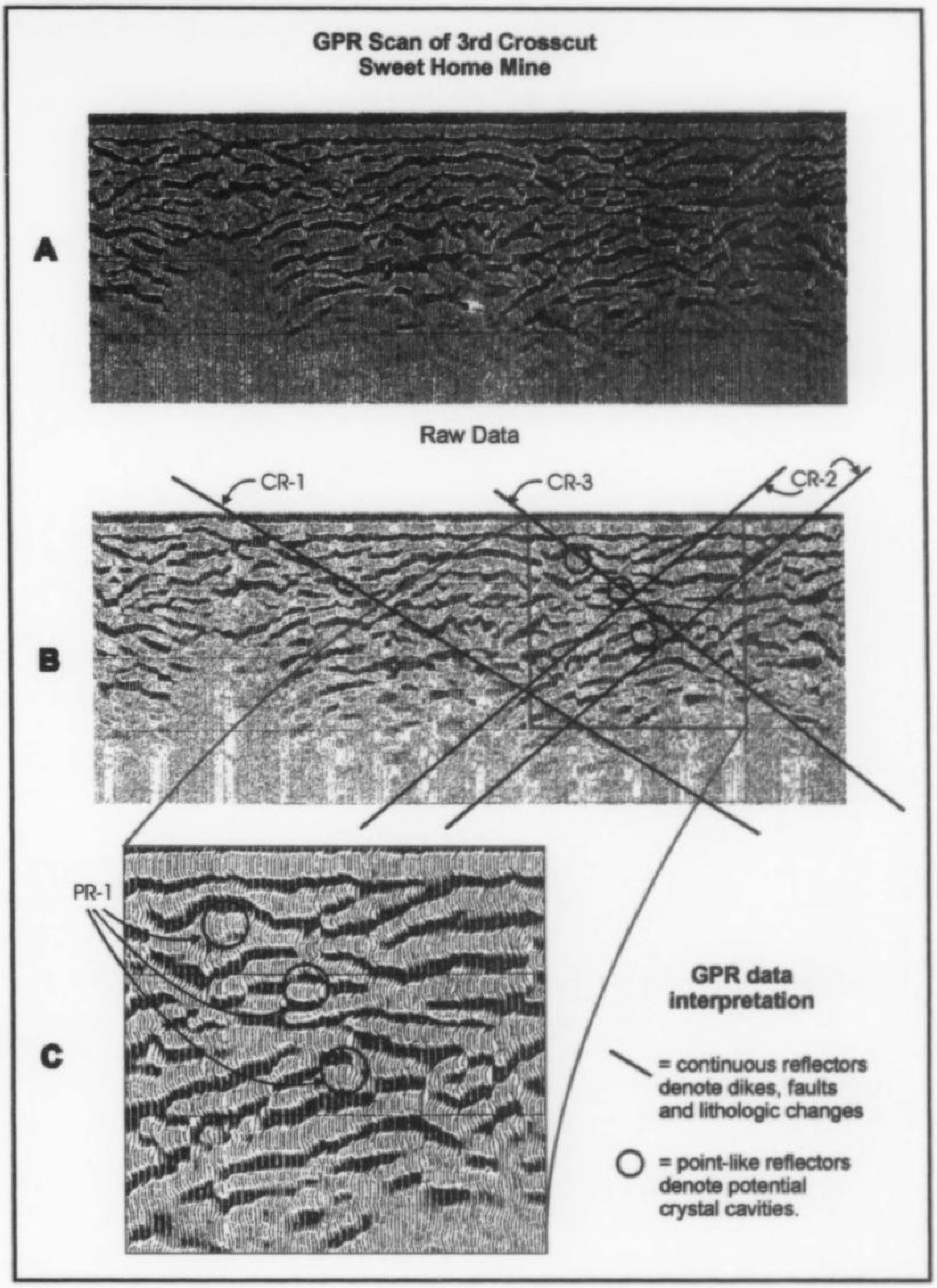


Figure 220. **GPR scan of the Sweet Home mine, showing raw data and interpretation.**

221, large purple dots). The pockets coincided with the fault intersections. Each of the pockets was small, measuring 12 to 16 inches in diameter and 2 inches wide. The second pocket produced the best material, about $40,000 worth (Fig. 216). The pocket was named the "Blueberry Pocket" because it contained several purple-blue octahedral fluorite specimens resembling blueberries (Fig. 215).

The GPR survey cost $7,000. Of this amount, Multiview Geoservices of Ontario, Canada, received $5,500 for bringing their equipment and personnel in from Canada. The balance went toward associated mine costs during the survey. Driving the 30 feet of tunnel to get to the target cost about $6,000. The high tunneling costs were due to careful drill probe work done prior to each blast. Total project costs, including GPR survey work and tunnel driving, were $13,000.

The tunnel was successful not only from a production standpoint, but it also showed us that very small pockets could be detected by the GPR system. Even though we did not find a large pocket with the system, we now had another tool with which to prospect. And small pockets obviously can be valuable.

GPR LIMITATIONS

Unfortunately, a major factor limited GPR's widespread use at the Sweet Home mine. A typical rhodochrosite pocket looks like a vertically oriented 14-inch-diameter x 2-inch-thick hollow "pancake" (imagine a pancake standing on edge). A 14-inch object is near the detection limit of the antenna used for the Sweet Home mine GPR survey. Because the pockets are usually lying inside a vertically oriented vein, most of our GPR scans were looking at them "head on" into their most narrow profile. It was like looking at a thin fish head-on underwater. So instead of scanning the side view of the "pancake"-shaped pockets, the GPR system only saw their end-views. With most of the targets already on the small side, 12 to 18 inches in diameter, the end-view perspective significantly cut down the GPR system's ability to see pockets; unfortunately, most of our target veins fell into this category.

The success we enjoyed in finding the "Blueberry Pocket" was because the survey angle used to scan this pocket zone was from a side-view perspective. In this discovery, the vein containing the "Blueberry Pocket" nearly paralleled the tunnel wall scanned by the GPR system, and thus, the GPR system saw the pocket's side

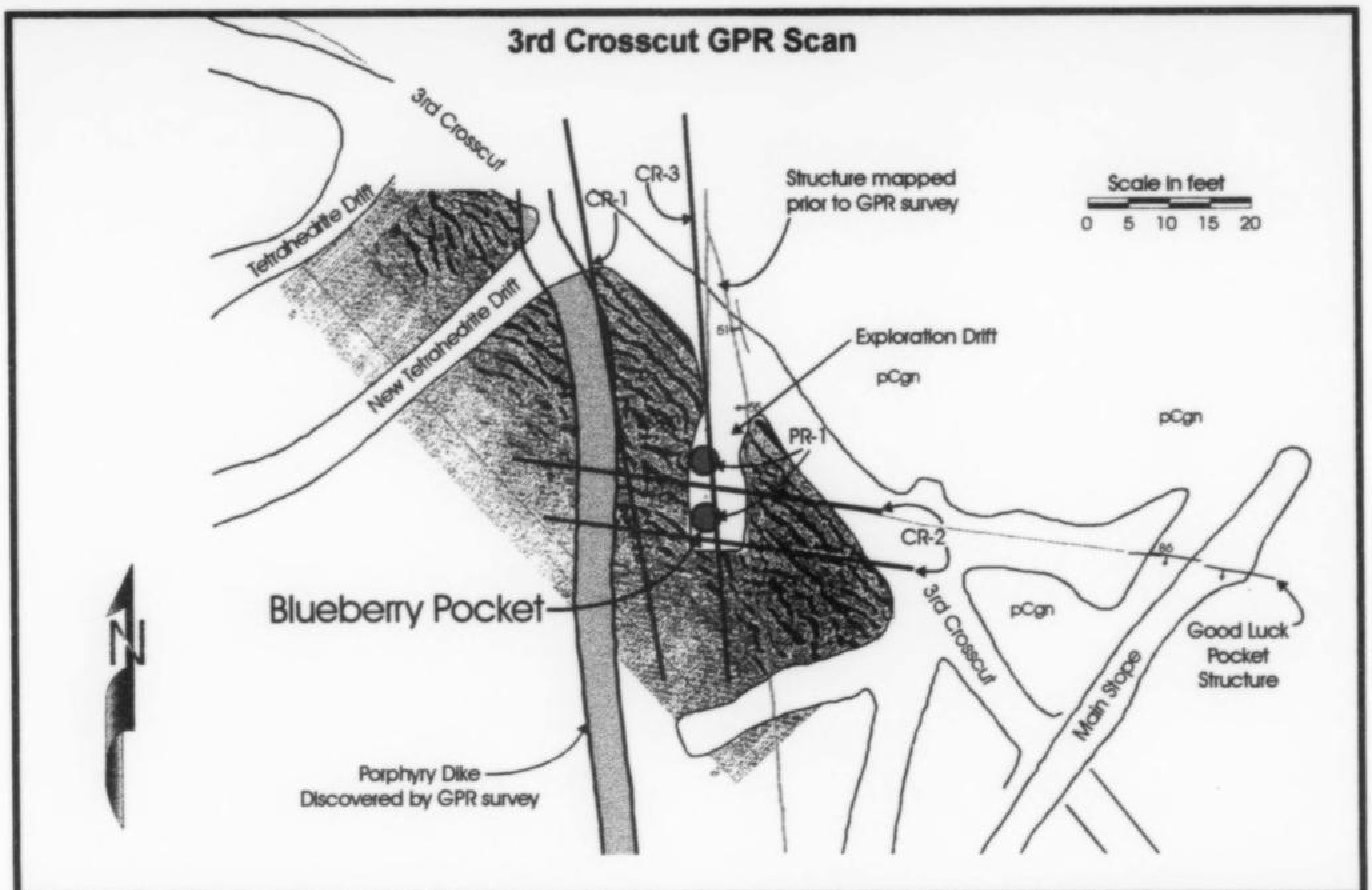


Figure 221. **Ground-penetrating radar response at the Sweet Home mine, showing correlation between mapped and subsequently discovered structures.**

view. If the tunnel walls had been perpendicular to the vein, the GPR system would not have discovered the pocket.

Most of the Sweet Home mine tunnels crosscut, or run perpendicular to, the pocket-bearing veins. And, because of their small size, most of the targets are at the detection limit of the GPR systems. These two factors limited the utility of GPR use at the Sweet Home mine.

During our survey we discovered a total of 12 GPR anomalies suggesting pocket locations. One of these produced the "Blueberry Pocket," two produced small low-value pockets (in the $1,000 range), and the other nine turned out to be small sulfide-filled pockets containing no open space or value.

Another difficulty in GPR use at the Sweet Home was that the coupling of the antenna to the wall was so rough that much of the signal energy was lost before it entered the wall rock. Air gaps between the antenna and wall rock were responsible for this. A 50% decrease in penetration depth because of this problem was estimated.

Because of the inherent "pancake" viewing problem, the antenna-to-wall coupling problem and the small pocket sizes, GPR has not become a "magic bullet" for finding rhodochrosite pockets at the Sweet Home mine. It was secretly hoped that GPR would find huge crystal cavities; in this initial study case, the discovery of huge pockets simply did not come to pass. GPR only found pockets at the Sweet Home mine when spatial orientations were correct, and such conditions were rarely encountered. From what we have learned at the Sweet Home mine, GPR will be useful in discovering hidden geologic structure, confirming previously mapped structure and periodically, locating small pocket anomalies.

One final point to make here is "Why go to all of the effort to use GPR?" Because mining costs are so high, saving a day or two of production costs by using GPR to avoid unproductive areas saves thousands of dollars. This is why so much effort goes into target definition by most mining companies. GPR can provide another way to help minimize production costs.

CONCLUSIONS

While results at the Sweet Home mine were mixed, GPR showed that it can be an important tool in mineral specimen exploration. The underground application was not the best training ground for GPR systems, however newer systems promise to better handle the harsh conditions found in underground situations. Based on results at the Sweet Home mine, the feeling is that GPR provides enough utility to be used as an aid to finding structural features such as faults and lithology changes. GPR also works for underground pocket exploration when the targets are large or properly oriented.

It should be noted here that GPR should work particularly well in surface surveys where targets are large or oriented such that a large profile will present itself to the system's signals. This may be very good news for future mineral specimen exploration by miners who try their hand at GPR, particularly those digging at the surface.

Improvements in software will continue to increase the utility of GPR systems. Also, system costs are coming down. In a few years, GPR may be available for a very low cost which would make specimen prospecting with this tool affordable by everyone.

REFERENCES

BAKKER, R. J. (1997) Clathrates: computer programs to calculate fluid inclusion V-X properties using clathrate melting temperatures. *Computers & Geosciences*, **23** (1), 1–18.

BANCROFT, P. (1973) *The World's Finest Minerals and Crystals*. The Viking Press, New York, 176 p.

BANCROFT, P. (1984) *Gem and Crystal Treasures*. Western Enterprises, Fallbrook, California, and Mineralogical Record, Inc., Tucson, Arizona, 488 p.

BEELER, H. (1933) A report on the Sweet Home Group of mines in Buckskin Gulch, Alma, Park County, Colorado. Unpublished, 29 p.

BEHRE, C. H., Jr. (1932) The Weston Pass mining district, Lake and Park counties, Colorado. *Colorado Scientific Society Proceedings* **13** (3), 53–75.

BEHRE, C. H. (1953) Geology and ore deposits of the west slope of the Mosquito Range [Colorado]. *U.S. Geological Survey Professional Paper* **235**, 176 p.

BELSER, C. (1956) Tungsten potential in Chaffee, Fremont, Gunnison, Lake, Larimer, Park, and Summit counties, Colorado. *U.S. Bureau of Mines Information Circular* **7748**, 31 p.

BILL, H., SIERRO, J., and LACROIX, R. (1967) Origin of colorization in some fluorites. *American Mineralogist*, **52**, 1003–1008.

BLOOM, D. N. (1965) Geology of the Horseshoe district and ore deposits of the Hilltop Mine, Park County, Colorado. Colorado School of Mines Ph.D. dissertation, 211 p.

BODE, R., and KLAUS, D. (1992) Neue rhodochrosit funde in der Sweet Home Mine bei Alma, Colorado. *Mineralien Welt* **3** (6), 43–45.

BODNAR, R. J. (1995) Fluid-inclusion evidence for a magmatic source for metals in porphyry copper deposits. *In* Thompson, J. F. H., ed., Magmas, fluids, and ore deposits. *Mineralogical Association of Canada Short Course*, **23**, 139–152.

BODNAR, R. J., and VITYK, M.O. (1994) Interpretation of microthermometric data for H_2O-NaCl fluid inclusions. *In* DeVivo, B., and Frezzotti, M. L., eds., Fluid inclusions in minerals: methods and applications. *Short Course of the Working Group "Inclusions in Minerals,"* Pontignano-Siena, 1–4 September 1994, 117–130.

BOOKSTROM, A. A. (1990) Igneous rocks and carbonate-hosted ore deposits of the Central Colorado Mineral Belt. *In* Beaty, D. W., Landis, G. P., and Thompson, T. B., Carbonate-hosted sulfide deposits of the Central Colorado Mineral Belt. *Economic Geology*, Monograph **7**, 45–65.

BUTLER, G. M. (1912) Appendix A—description of the ore and gangue minerals occurring near Alma, Colorado. *In* Patten, H. B., Hoskin, A. J., and Butler, G. M., Geology and ore deposits of the Alma district, Park County, Colorado. *Colorado Geological Survey Bulletin* **3**, 239–245.

BUTLER, R. D., and SINGEWALD, Q. D. (1940) Zonal mineralization and silicification in the Horseshoe and Sacramento districts, Colorado. *Economic Geology*, **35** (7), 793–838.

CAIRNCROSS, B., and DIXON, R. (1995) *Minerals of South Africa*. Geological Society of South Africa, Johannesburg, 61 p.

CALAS, G. (1972) On the blue color of natural banded fluorites. *Mineral Magazine*, **38**, 977–979.

CAPLAN, A. (1936) Colorado rhodochrosite. *Rocks and Minerals*, **11** (3), 35.

CAPLAN, A. (1980) An interview with Allan Caplan. *Mineralogical Record*. **11**, 351–360.

COOK, R. B. (1993) Connoisseur's choice: rhodochrosite, Alma, Park County, Colorado. *Rocks and Minerals*, **68** (1), 40–43.

CORN, R. M. (1957) The geology of the Mount Bross-Buckskin Creek area, Park County, Colorado. Colorado School of Mines M.S. thesis, 128 p.

DANA, E. S. (1898) *Catalogue of American Localities of Minerals*. John Wiley and Sons, New York, 51 p. [Reprinted from *The System of Mineralogy of James Dwight Dana, 1837–1868*, 6th ed., John Wiley and Sons, New York, 1134 p.]

DAVIS, J. L., and ANNAN, A. P. (1989) Ground penetration radar for high-resolution mapping of soil and rock stratigraphy. *Geophysical Prospecting*, **37**, 531–551.

DEER, W. A., HOWIE, R. A., and ZUSSMAN, J. (1962) *Rock-Forming Minerals*. Vol. 5. *Non-silicates*. Longman Group Ltd., London, 371 p.

DEL RIO, S. M. (1960) *Mineral Resources of Colorado, 1st Sequel*. State of Colorado Mineral Resources Board, Denver, Colorado, 764 p.

DEMPSEY, A., and VOYNICK, S. (1994) Home Sweet Home Mine. *Mines Magazine*, **84** (2), March-April. Colorado School of Mines Alumni Association, Golden, Colorado, 6–8.

ECKEL, E. (1961) Minerals of Colorado: a 100-year record. *U.S. Geological Survey Bulletin* **1114**, 399 p.

EMMONS, S. F. (1886) Geology and mining industry of Leadville, Colorado. *U.S. Geological Survey Monograph* **12**, 770 p.

ENDLICH, F. M. (1878) Mineralogical report—catalogue of minerals found in Colorado. *In* Hayden, F. V., Tenth annual report of the U.S. Geological and Geographic Survey of the territories, embracing Colorado and parts of adjacent territories, report of progress of exploration for the year 1876. *U.S. Geological and Geographical Survey of the Territories*, 133–159.

FISHER, E., MCMECHAN, G. A., and ANNAN, A. P. (1992) Acquisition and processing of wide-aperture ground penetrating radar data. *Geophysics*, **57**, 495.

FRAZIER, S., and FRAZIER, A. (1996) Inside the Sweet Home Mine. *Lapidary Journal*, **50** (4), 28–33, 102, 104.

FUBINI, B., and STONE, F. S. (1983) Physico-chemical properties of $MnCO_3$ and MnO-CaO solid solutions. *J. Chem. Soc. Faraday Trans. I*, **79**, 1215–1227.

GOLDSMITH, J. R., and GRAF, D. L. (1960) The system CaO-MnO-CO_2: solid solution and decomposition relations. *Geochem. Cosmochim. Acta* **11**, 310–334.

GOLDSTEIN, R. H., and REYNOLDS, T. J. (1994) Systematics of fluid inclusions in diagenetic minerals. *SEPM Short Course 31*. SEPM (Society of Sedimentary Geology), Tulsa, 199 p.

GRESSMAN, T. (1988) The Denver Museum of Natural History. *Mineralogical Record*, **19** (4), 263–270.

HENDERSON, C. W. (1926) Mining in Colorado. *U.S. Geological Survey Professional Paper* **138**, 263 p.

HONEA, R. M. (1992) unpublished petrographic report for Sweet Home Rhodo, Inc.

INGLE, D. (1958) Rhodochrosite in Colorado. *Rocks and Minerals*, **33** (11–12), 499.

JONES, R. (1986) Rhodochrosite: hot, pink, & pretty. *Rocks and Minerals*, **61** (1), 7–12.

JONES, R. (1993) Colorado's rhodochrosite. *Rock and Gem*, **23** (2), 42–43, 45–46.

JONES, R. (1994) Sweet red rhodochrosite. *Rock and Gem*, **24** (11), 48–51, 77.

KILE, D. E., and LEES, B. K. (1993a) Recent activity at the Sweet Home Mine, Park County, Colorado. *Friends of Mineralogy-Colorado Chapter Newsletter*, **1** (January), 4–5.

KILE, D. E., and LEES, B. K. (1993b) Recent developments at the Sweet Home Mine, Park County, Colorado. *Friends of Mineralogy-Colorado Chapter Newsletter*, **5** (September), 4–6.

KOSNAR, R. A. (1979a) What's new in Colorado minerals? *Mineralogical Record*, **10** (6), 329–332.

KOSNAR, R. A. (1979b) The Home Sweet Home Mine. *Mineralogical Record*, **10** (6), 333–338.

KOSNAR, R.A., and MILLER, H. W. (1976) Crystallized minerals of the Colorado Mineral Belt. *Mineralogical Record*, **7** (6), 278–307.

KUNZ, G. F. (1887) Rhodochrosite from Colorado (Mineralogical notes). *American Journal of Science*, 3d ser., **34** (204), 477–478.

LEES, B. K. (1994) Sweet Home Mine update. *Mineral News*, **10** (12), 1, 5.

LEES, B. K. (1995) Discovery, identification, and description of minerals found during mining 1992–1995. Personal communication to Jack Murphy and James Hurlbut.

MACHADO, J. E. (1967) Geology and ore deposits of Pennsylvania Hill, Alma district, South Park, Park County, Colorado. Colorado School of Mines M.S. thesis, 153 p.

MILLER, H. W. (1971) Rhodochrosite crystal localities in the West. *Mineralogical Record*, **2** (3), 105–110, 143.

MODRESKI, P. J. (1988) The silver content of galena and sulfosalt minerals from hydrothermal ore deposits in Peru, Colorado, and New Mexico. *In* Modreski, P. J., ed., *Mineralogy of Precious Metal Deposits—A Symposium on the Mineralogy of Gold and Silver Deposits in Colorado and Other Areas*. Friends of Mineralogy, Colorado Chapter and the Department of Geology, Colorado School of Mines, 70–79.

MOORE, T. (1993) What's new in minerals? Tucson show 1993. *Mineralogical Record*, **24** (3), 219–230, 237–238.

MUNTYAN, B. L. (1996) Colorado fluorite. *Rocks and Minerals*, **71**, 164–179.

MURPHY, J. A. (1994) The discovery of the Alma King rhodochrosite crystal. *Museum Monthly*, **3** (9), opposite pages 1 and 16.

MURPHY, J. A. (1997) Sweet Home mine rhodochrosite wall at the Denver Museum of Natural History. *Rocks and Minerals*, **72** (4), 240–243.

MUTSCHLER, F. E., WRIGHT, E. G., LUDDINGTON, S., and ABBOTT, J. T. (1981) Granite molybdenite systems. *Economic Geology*, **76**, 874–897.

NASSAU, K. (1978) The origins of color in minerals. *American Mineralogist*, **63**, 299–301.

PALACHE, C., BERMAN, H., and FRONDEL, C. (1944) *The System of Mineralogy of J. D. Dana and E. S. Dana, Yale University, 1837–1892*. 7th ed., vol. 1, John Wiley and Sons, New York, 834 p.

PALACHE, C., BERMAN, H., and FRONDEL, C. (1951) *The System of Mineralogy of J. D. Dana and E. S. Dana, Yale University, 1837–1892*. 7th ed., vol. 2, John Wiley and Sons, New York, 1124 p.

PATTON, H. B., HOSKIN, A. J., and BUTLER, G. M. (1912) Geology and ore deposits of the Alma district, Park County, Colorado. *Colorado State Geological Survey Bulletin* **3**, 284 p.

PIERSON, C. T., and SINGEWALD, Q. D. (1953) Results of reconnaissance for radioactive minerals in parts of the Alma district, Park County, Colorado. *U.S. Geological Survey Circular* **294**, 9 p. [Also published as *U.S. Geological Survey Trace Element Investigations* **TEI-248**, 28 p.]

PRZIBRAM, K. (1935) Fluorescence of fluorite and the bivalent europium ion. *Nature*, **135**, 100–102.

RAABE, K. C., and SACK, R. O. (1984) Growth zoning in tetrahedrite-tennantite from the Hock Hocking Mine, Alma, Colorado. *Canadian Mineralogist*, **22** (4), 577–582.

REITZ, J. R., and MILFORD, F. J. (1962) *Foundations of Electromagnetic Theory*. Addison-Wesley.

ROBINSON, G. (1993) What's new in minerals? Colorado. *Mineralogical Record*, **24** (1), 46.

ROOTS, R. D. (1951a) Rhodochrosite in Colorado. *Rocks and Minerals*, **26** (3–4), 170.

ROOTS, R. D. (1951b) Pyrite. *Rocks and Minerals*, **26** (11–12), 598–600.

SCAIFE, J. E., and ANNAN, A. P. (1991) Ground penetrating radar—a powerful, high resolution tool for mining engineering and environmental problems. Paper presented at 93rd CIM Annual General Meeting, Vancouver, B.C., April 29–May 1, 1991.

SENECAL, J. (1994) How sweet it is: mineralogy of the Sweet Home Mine, Alma, Park County, Colorado. Department of Earth

Sciences internship research paper, Denver Museum of Natural History, 19 p.

SILBERMAN, M. L. (1983) K-Ar age determination of Tertiary hydrothermal alteration and mineralization in the Great Basin, western U.S. *Geothermal Research Council Special Report* **13**, 287–303.

SILBERMAN, M. L. (1995) Unpublished isotope and age determination report for Sweet Home Rhodo, Inc.

SINGEWALD, Q. D. (1932) Igneous history of the Buckskin Gulch stock, Colorado. *American Journal of Science*, 5th ser., **24**, 52–67.

SINGEWALD, Q. D. (1947) Lode deposits of Alma and Horseshoe districts, Park County. *In* Vanderwilt, J. W., ed., *Mineral Resources of Colorado*. State of Colorado Mineral Resources Board, Denver, Colorado, 336–346.

SINGEWALD, Q. D., and BUTLER, B. S. (1931a) Preliminary geologic map of the Alma mining district, Colorado. *Colorado Scientific Society Proceedings*, **12** (9), 295–308.

SINGEWALD, Q. D., and BUTLER, B. S. (1931b). Preliminary report on the geology of Mount Lincoln and the Russia Mine, Park County, Colo. *Colorado Scientific Society Proceedings*, **12** (12), 389–406.

SINGEWALD, Q. D., and BUTLER, B. S. (1933) Suggestions for prospecting in the Alma district, Colorado. *Colorado Scientific Society Proceedings*, **13** (4), 89–131.

SINGEWALD, Q. D., and BUTLER, B. S. (1941) Ore deposits in the vicinity of the London fault of Colorado. *U.S. Geological Survey Bulletin* **911**, 74 p.

SMAKULA, A. (1950) Color centers in calcium fluoride and barium fluoride crystals. *Physics Review*, **77**, 480–409.

SMITH, B. (1993) Sweet Home Mine. *Mineralogical Record*, **24** (1), 55.

SMITH, J. A. (1883) *Report on the Development of the Mineral, Metallurgical, Agricultural, Pastoral, and Other Resources of Colorado for the Years 1881 and 1882*. Chain and Hardy Publishers, Denver, 150 p.

STEVENS, D. N. (1965) Geology and geochemistry of ore deposits and wallrock of the Buckskin Joe Mine and vicinity, Buckskin-Mosquito mining district, Park County, Colorado. Colorado School of Mines Ph.D. dissertation, 97 p.

TAYLOR, H. P., Jr. (1974) The application of oxygen and hydrogen isotopic studies to problems of hydrothermal alteration and ore deposition. *Economic Geology*, **69**, 843–883.

TELFORD, W. M., GELDART, L. P., SHERIFF, R. E., and KEYS, D. A. (1976) *Applied Geophysics*. Cambridge University Press.

VANDERWILT, J. W. (1947) *Mineral Resources of Colorado*. State of Colorado Mineral Resources Board, Denver, Colorado, 547 p.

VOYNICK, S. M. (1992) Alma mining district. *Rock and Gem*, **22** (3), 56–59, 66, 67.

VOYNICK, S. M. (1994a) *Colorado Rockhounding*. Mountain Press Publishing Company, Missoula, Montana, 372 p.

VOYNICK, S. M. (1994b) Specimen mining—Sweet Home mine produces world's best rhodochrosite. *In* Parkhill, S. M., ed., *Compressed Air*, **99** (2), 6–13.

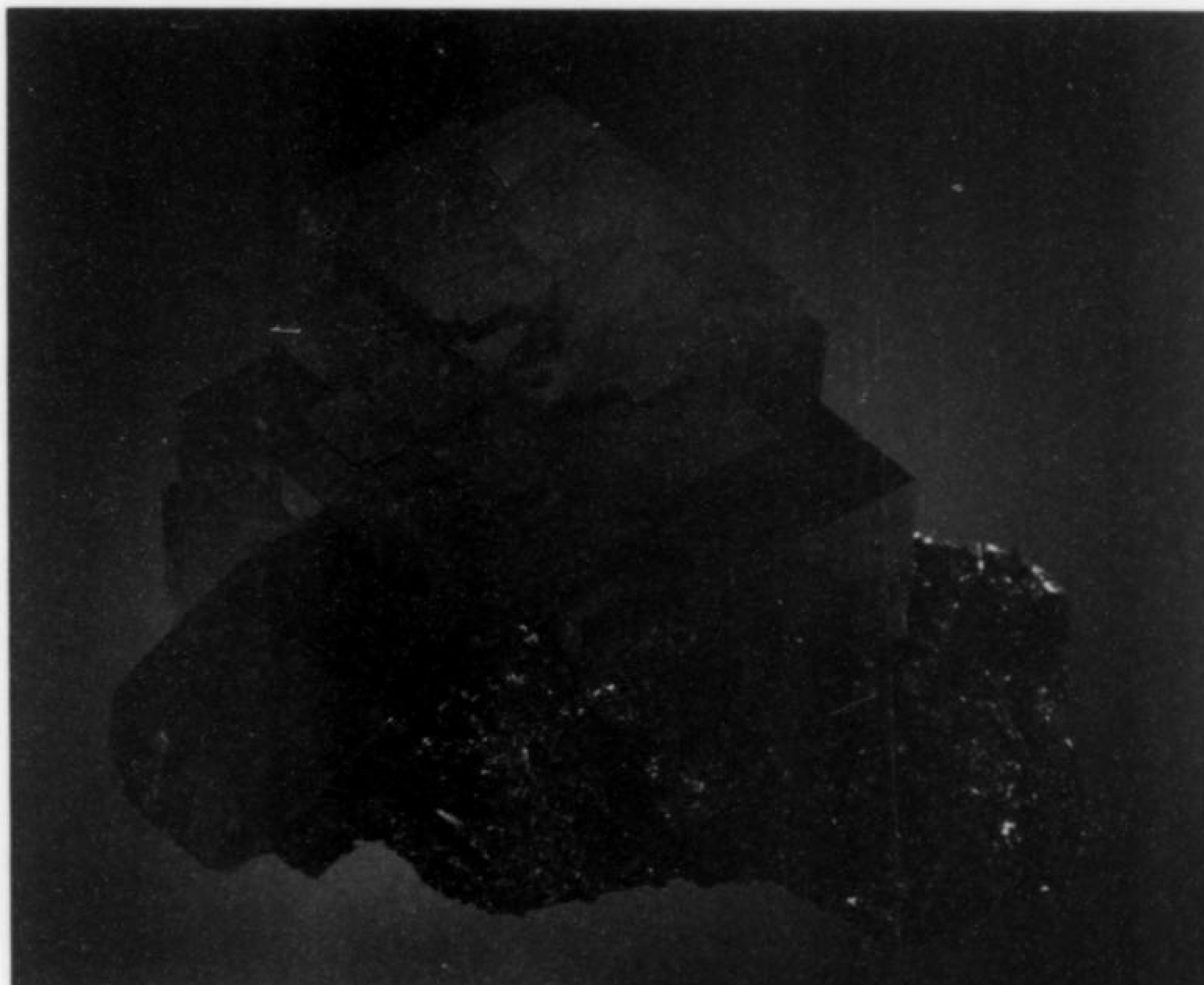
WALLACE, S. P. (1995) The Climax type molybdenite deposits: What they are, where they are, and why they are. *Economic Geology*, **90** (5), 1359–1380.

WELLS, R. C. (1937) Analyses of rocks and minerals from the laboratory of the United States Geological Survey, 1914–36. *U.S. Geological Survey Bulletin* **878**, 134 p.

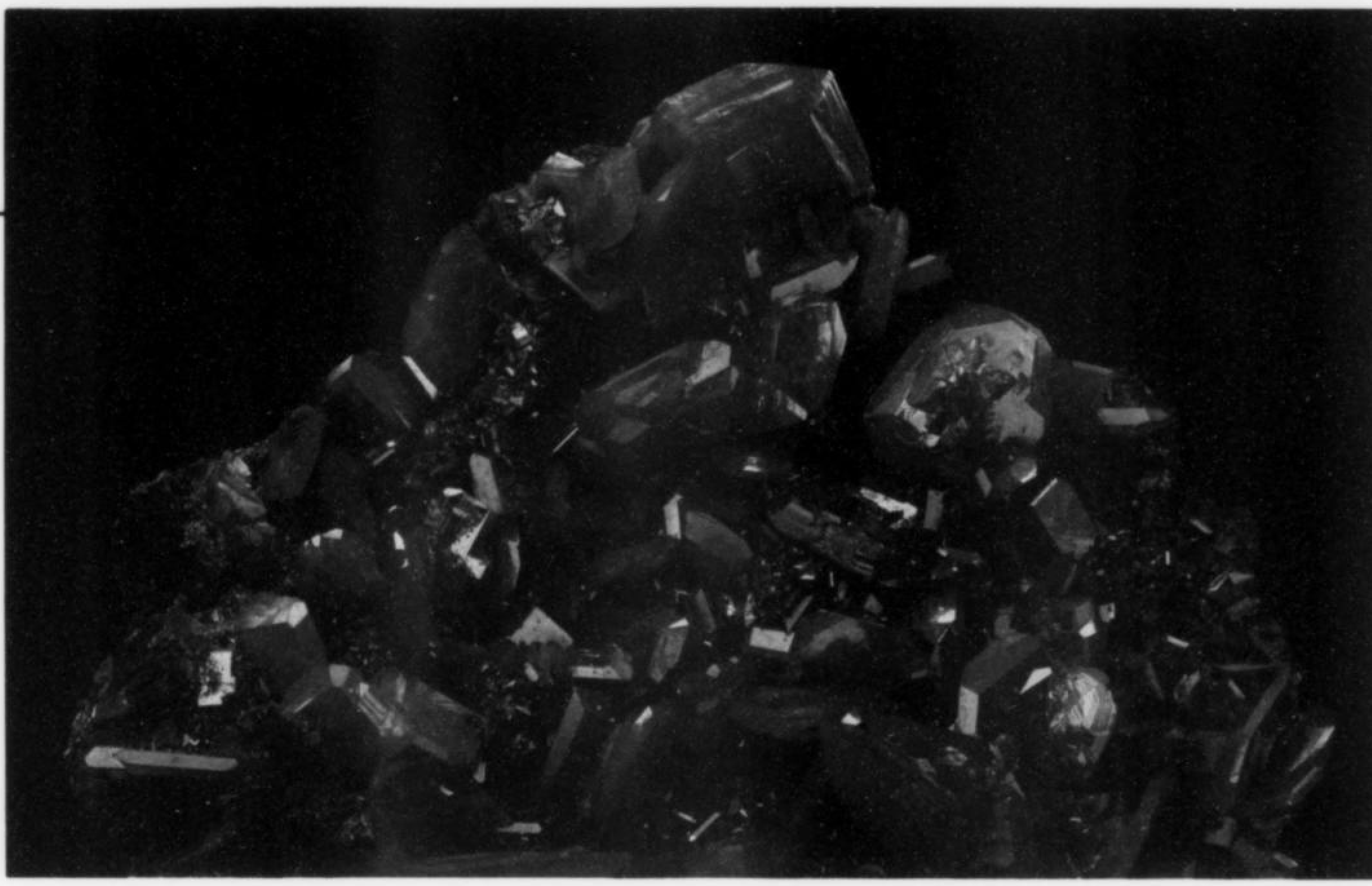
WENRICH, K. J., LEES, B., REYNOLDS, T. J., and SILBERMAN, M. L. (1995) Specimen mining: profits from the Sweet Home mine, Alma, CO. Short Courses and Exposition, *Northwest Mining Association Abstract Book*, December 4–8, Spokane, Washington, 19–20.

WHITE, G. M. (1981) Colorado in the old days (Letters). *Mineralogical Record*, **12** (3), 135–136.

WHITE, W. H., BOOKSTROM, A. A., KAMILLI, R. J., GANSTER, M. W., SMITH, R. P., RANTA, E. E., and STEINNINGER, R. C. (1981) Character and origin of Climax-type molybdenum deposits. *Economic Geology Seventy Fifth Anniversary Volume*, 270–316.



Manganese Ore at the Sweet Home mine, Alma, Colorado, 1898 — *Wendell E. Wilson ©1994*



Arizona Dealers

Bitner's, Inc.
42 West Hatcher
Phoenix, Arizona 85021
(602) 870-0075
Wholesale Minerals & Fossils, by the piece, pound or flat, since 1945

Copper City Rock Shop
John & Karen Mediz
566 Ash Street
Globe, AZ 85501
Tel: (520) 425-7885
FAX: (520) 425-4506
Southwestern minerals since 1970. See us at shows or visit our store (call first).

Kino Rocks & Minerals
6756 S. Nogales Highway
Tucson, Arizona 85706
(520) 294-0143
9–11:15/Noon–5:30
(Closed Sun.)
No Catalog—No List

David Shannon Minerals
David & Colleen
6649 E. Rustic Drive
Mesa, Arizona 85215
(602) 985-0557
Minerals, Boxes & Supplies.
Send 3 stamps for list.

Em's Gems Plus Three
Em & Ogle Love
8846 E. 35th Circle
Tucson, Arizona 85710
(520) 886-6942
Fine moderately priced specimens for collectors and museums. Shows only.

Crystal Pockets
George Godas
6304 S. Clark Drive
Tempe, Arizona 85283
(602) 820-3067
Arizona Lead Mineral

Evan Jones Minerals
3520 N. Rose Circle Dr.
Scottsdale, AZ 85251
Tel/Fax: (602) 946-5826
By Appointment Only.
Fine Minerals for Collectors.
Specializing in Arizona, Mexico & Worldwide Classics.
We Buy Collections.

Top-Gem Minerals
1201 B North Main Street
Tucson, Arizona 85705
Tel: (520) 622-6633
FAX: (520) 792-2928
Mon-Fri 8:30–4:30
and by Appt.
No Catalog or List
Wholesale Only
Mex. & Tenn. minerals, boxes

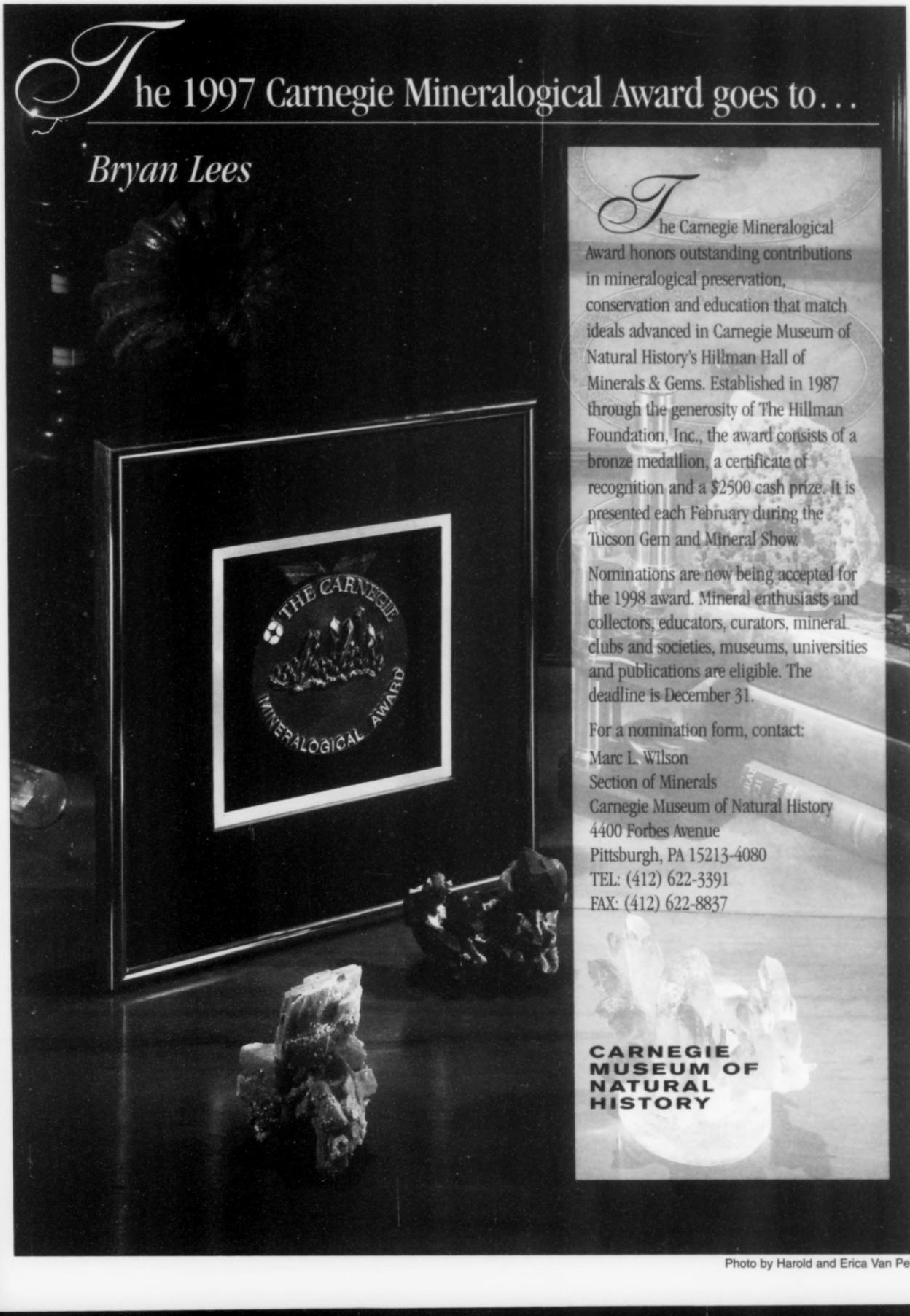
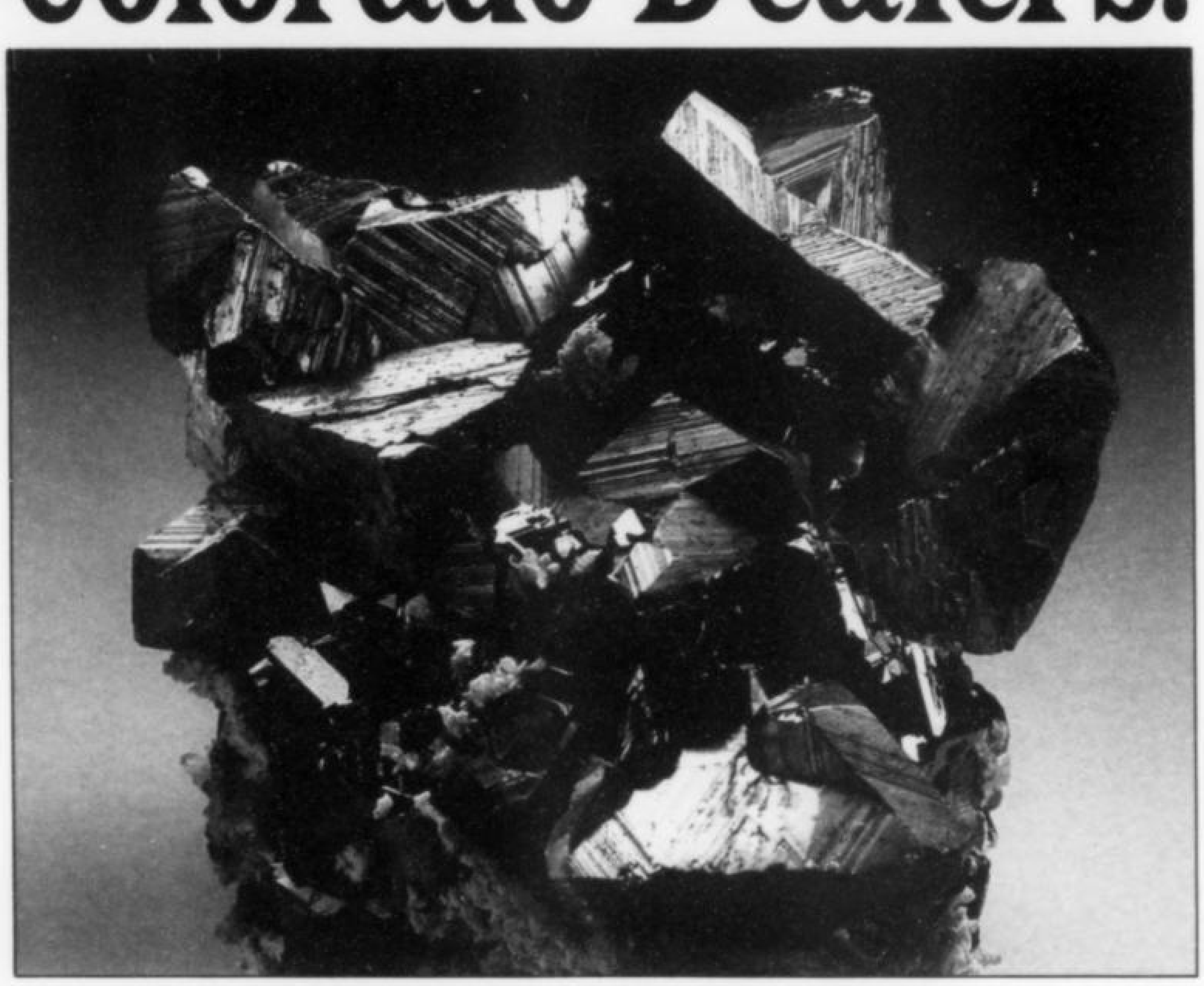


Photo by Harold and Erica Van Pelt

Colorado Dealers!



DENVER MUSEUM OF NATURAL HISTORY WEW

COLORADO MINERAL AND FOSSIL SHOW
Holiday Inn Denver North
SEPT. 16-20, 1998
10 a.m. to 7 p.m. Daily
INFO: P.O. Box 999 • Evergreen, CO 80437

David Bunk Minerals
David Bunk
1441 W. 46th Street, #8
Denver, CO 80211
303-477-6897 (by appointment)
Colorado & Worldwide Specimens

Columbine Mineral Shop
Benjy & Liz Kuehling
P.O. Box 541
633 Main Street
Ouray, CO 81427
970-325-4345, 9 a.m. to 9 p.m.
Open 7 days, May 1-Oct. 31
Off-season by Appointment
Fine Minerals for Collectors

The Crystal Group
George Fisher & Doug Collyer
511 Foothills Road
Colorado Springs, CO 80906
719-634-0635 (By Appt. Only)
Amazonite & Smoky Quartz
Fine Colorado Minerals

Genesis Epoch
Mel & Pam Bersch
248 Little Park Rd.
Grand Junction, CO 81503
970-242-3134 (call for appt.)
Tsumeb Minerals, Western Colo.
Fluorite/Amethyst & Fossils
E-mail: MPBERSCH@aol.com

Glacier Peak Art, Gems & Minerals
Joseph & Susan Dorris
1686 So. 21st Street
Colorado Springs, CO 80904
719-442-6630
Producing Colorado Amazonite & Smoky Quartz. Beginner to Advanced, Worldwide Minerals
http://www.frii.com/~glacier

Green Mountain Minerals
Stanley Korzeb
13993 E. Arizona Ave.
Aurora, CO 80012
303-368-1209 (Call for Appt.)
Species, Fine Minerals, write for List

Bill Hayward Minerals
Bill & Christopher Hayward
3286 Quitman Street
Denver, CO 80212
303-455-1977 (Call for Appt.)
Colorado & Pikes Peak Minerals

L & T Creations
Lee A. McKinney
1800 Winfield Drive
Lakewood, CO 80215
By Appt. Only 303-232-6451
Colorado Amazonite

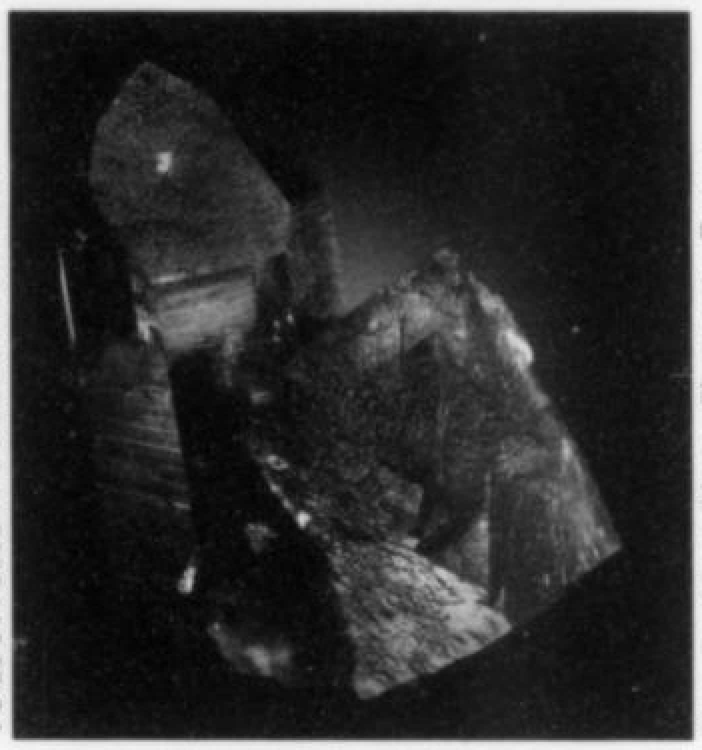
LJP—Colorado
Larry & Carmen Piekenbrock
1180 York Avenue
Cañon City, CO 81212–8612
719-275-7530 (Call for Appt.)
Fine Minerals, Micros, etc.
WWWeb:http://www.collectors-mall.com/

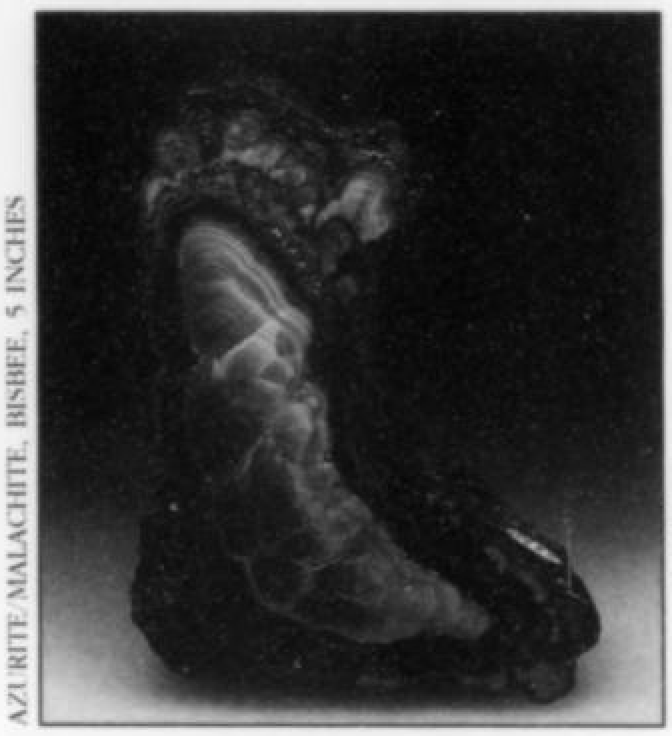
George Witters Minerals
George & Cindy Witters
2210 Park Lake Dr.
Boulder, CO 80301
303-664-5864
FAX: 303-926-1933
Fine Minerals, Worldwide
By Appointment Only

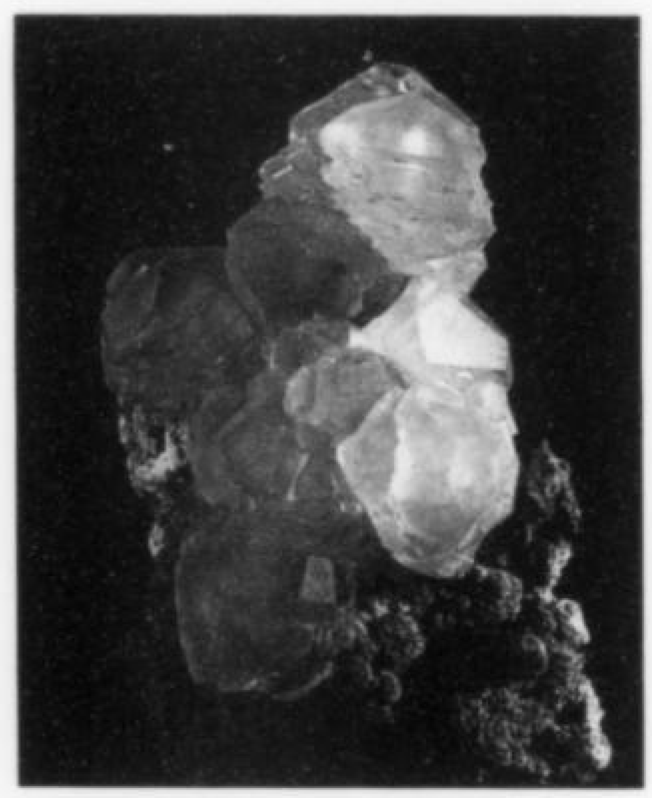
Mountain Minerals International
Dudley Blauwet
P.O. Box 302
Louisville, CO 80027-0302
303-665-0672
FAX: 303-664-1009
Buy/Sell/Trade
Minerals, Gems, Gem Rough

The Sunnywood Collection
Bill & Elsie Stone
12068 E. Amherst Place
Aurora, CO 80014
303-368-7497 (by Appt. only)
Premium Minerals, Fossils & Carvings Artistically Mounted
www.sunnywood.com

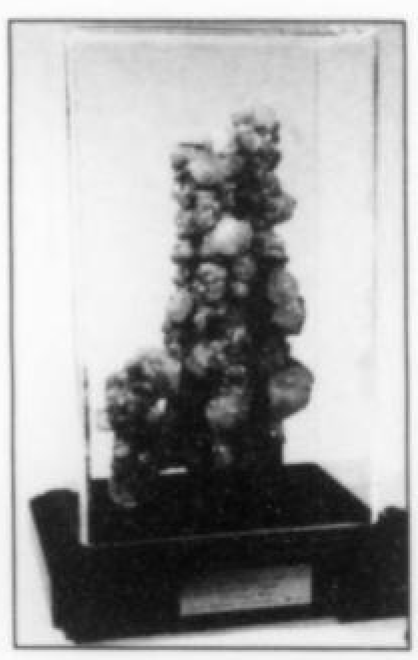
XTAL—Dennis Beals
Dennis & Diane Beals
6006 S. Holly St., Suite 256
Englewood, CO 80111
303-771-9225 (by Appt. only)
FAX: 303-771-9308
Fine Mexican minerals & more

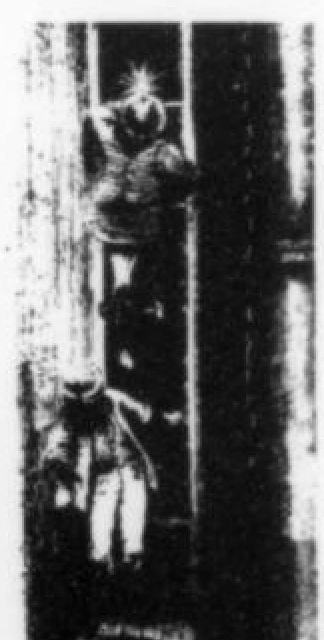




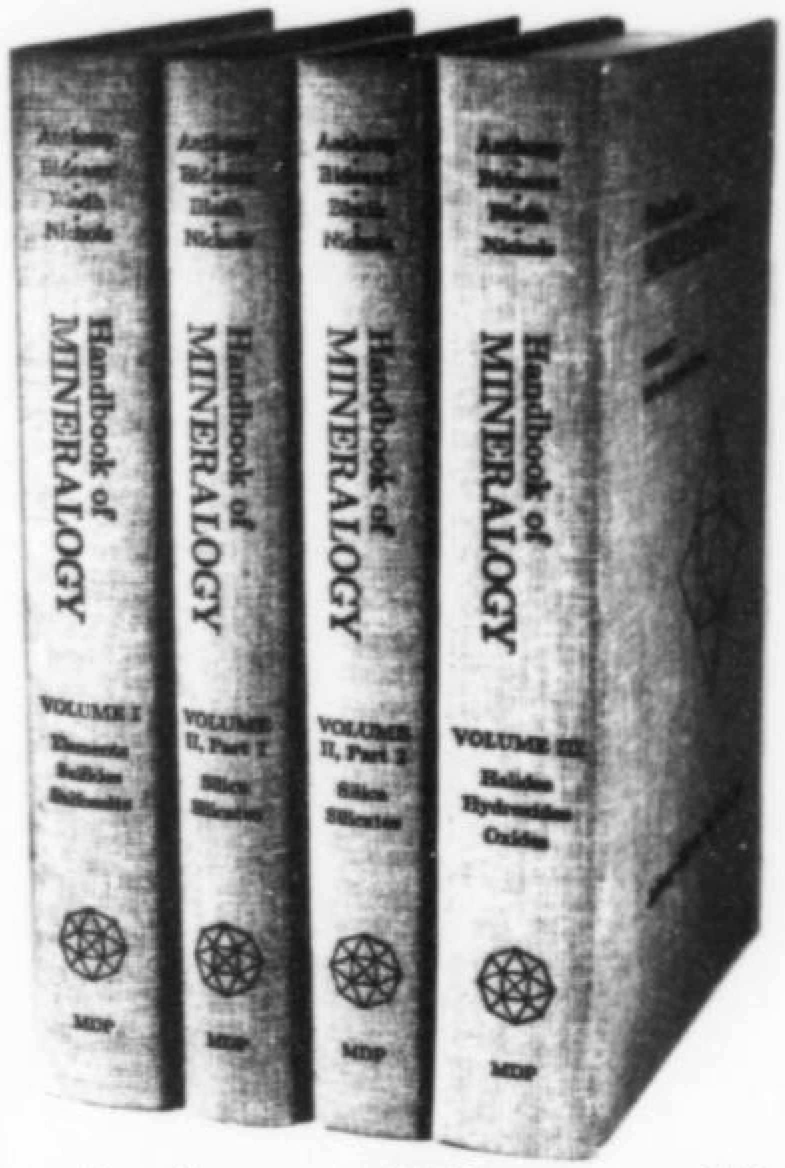


Cobaltoan, Calcite, Mashamba West mine, Zaire, 3.8 cm; Pamela Zilly Photo





Handbook of MINERALOGY



From the
Mineralogical Magazine

"This work is thus an extremely comprehensive data source. . . . The typography is clear, the data are up-to-date and there appear to be almost no errors . . . it will surely be an indispensable work for all mineralogists to have available. The price is very reasonable for the size and for the standard of the production and this should help make it available in all earth science libraries and on the personal shelves of working mineralogists."

Anthony • Bideaux • Bladh • Nichols

NEW!

NOW AVAILABLE

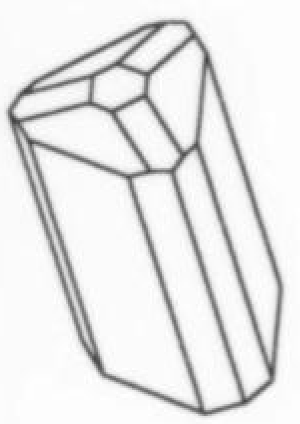
Vol. III—Halides, Hydroxides, Oxides—628 p., 1997
US$100.00 + $6.00 S&H
(ISBN 0-9622097-2-4)

Vol. II—Silica and Silicates
904 p. in 2 books, 1995
US$144.00 + $7.50 S&H
(ISBN 0-9622097-1-6

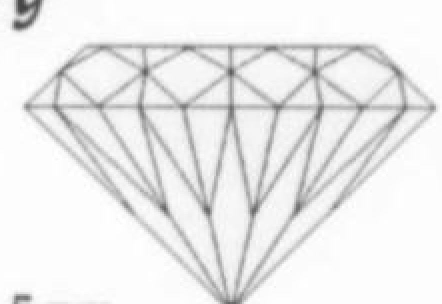
Vol. I—Elements, Sulfides, Sulfosalts—588 p., 1990
US$94.00 + $6.00 S&H
(ISBN 0-9622097-0-8)

VISA/MASTERCARD ACCEPTED

MINERAL DATA PUBLISHING
FULFILLMENT SERVICES INC.
1955 W. Grant Rd., Suite 230
Tucson, Arizona 85745 USA
Tel: (520) 798-1513 FAX: (520) 798-1514



Phoenix Treasure Market of Minerals, Fossils, Gems & Jewelry



Phoenix Civic Plaza - Hall C

Third & Washington St., Phoenix, AZ

November 20-22, 1998

Hours: Friday, 10 am - 7 pm; Saturday, 10 am-6 pm; Sunday, 10 am - 5 pm

Produced by GeoExpositions and hosted by The Mineralogical Society of Arizona

Admission: $5.00/3 days
Children under 14 free with adult

Spring Show in the Rockies

Minerals - Fossils - Gems - Jewelry

Holiday Inn-Denver North & Best Western-Central Denver

4849 Bannock St, & 200 W. 48th Ave.

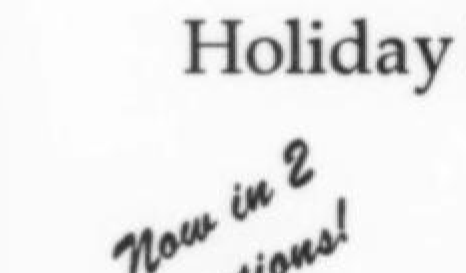
Now in 2 locations!

April 16-18, 1999

Hours: Friday & Saturday, 10 am - 7 pm; Sunday, 10 am - 5 pm

FREE Admission - OPEN to the public - FREE parking

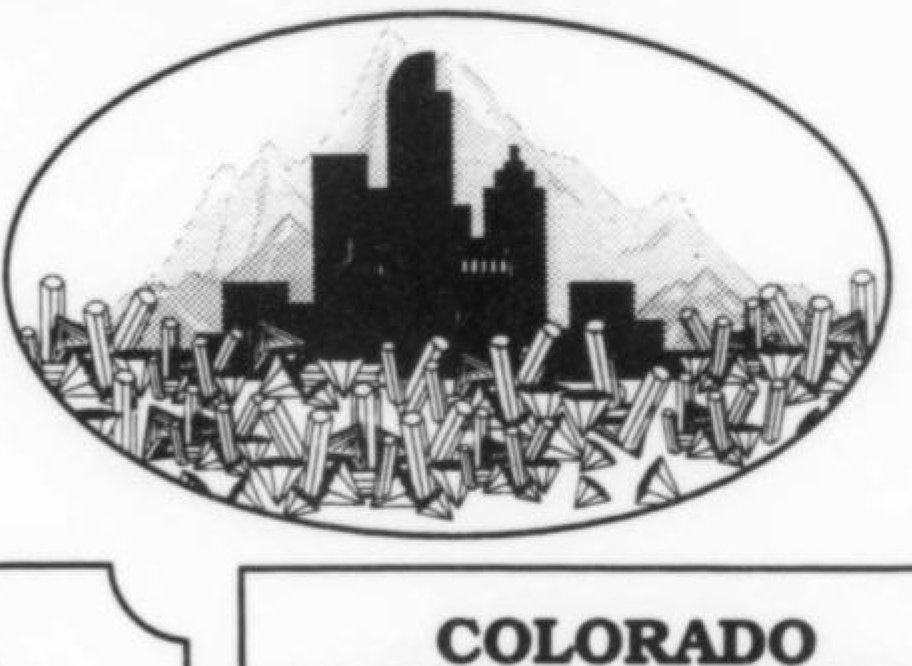
Wholesale and Retail Dealers



Show Info: GeoExpositions, P.O. Box 5054, Golden, CO 80401
(303) 278-1218 (phone or FAX) : (303) 978-9926
Karen Wenrich & Regina Aumente

Mineral, Gem, Jewelry, Bead and Fossil Shows

DENVER 1998



BACK ISSUES!

v.1/#1 Early Amer. collectors, Mirabilite (Chile), Mult. Japan-law Qtz. twins, Lunar minerals (*facsimile:* **$20**)	**v.1/#2** Moctezuma mine (Mexico), Cleaning Minerals, Lake Baikal (Russia), Tilasite (Bisbee), Minas Gerais *Original* **$30** (*facsimile:* **$20**)	**v.1/#3** Rutile (CT), Eakerite, Cenosite (Switz.), Mineral Rings, Cornetite (AZ), Basaluminite (*facsimile:* **$20**)	**v.1/#4** Colombia Emeralds, Natrolite (OR), Benstonite (IL), Långban (Sweden) *Original* **$30** (*facsimile:* **$20**)	**v.2/#1** Delafossite (WY), Ancylite (PA), Stevensite, Lancasterite (PA), Monte Redondo (Portugal) (*facsimile:* **$20**)
v.2/#2 Chessy (France), Blue Quartz, Panasqueira (Portugal), X-ray crystallography (pt. I) (*facsimile:* **$20**)	**v.2/#3** Rhodochrosite (West US), Chalcoalumite (Bisbee), Ytterby (Swed.), X-ray crystallography (pt. II) (*facsimile:* **$20**)	**v.2/#4** California: New Minerals, Churchite, Florencite-(Nd), Antarcticite; X-ray crystallography (pt. III) (*facsimile:* **$20**)	**v.2/#5** Gold Hill (UT), Rose Quartz, Grandview mine (AZ), Crandallite (VA), Early American Mineral Specimens (*facsimile:* **$20**)	**v.2/#6** Apache mine (AZ), Opal structure, Mont St-Hilaire (Que.), Museum Record, Spec. Holders (*facsimile:* **$20**)

v.8/#5 Characterization of New Species, Twinning, Axinite (Brazil), Green River (WY) **$10**

v.8/#6 California Issue Benitoite, Gold, L.A. County Museum, Himalaya mine **$10**

v.9/#3 Kalahari rhodochrosite, Paterson (NJ), Brumado district (Brazil), Bosch Collection **$10**

v.9/#4 Elmwood (TN), Chester (MA), Pyrite XL Forms **$10**

v.9/#5 Turkish Kämmererite, Afghan pegmatites, Chuquicamata (Chile) **$10**

Order From: Circulation Manager
Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740

FAX YOUR CREDIT CARD ORDERS!
520-544-0815

MasterCard VISA

Postage $1 per copy–Order 10 copies or more and **we pay all postage.**

Supplies are Liminted

BACK ISSUES!

v.9/#6 Libethenite (Zambia), Quartz & Pyrite (WA), Hydroboracite (CA) **$10**

v.10/#1 Hydroxyl-herderite (Brazil), Books on U.S. minerals **$10**

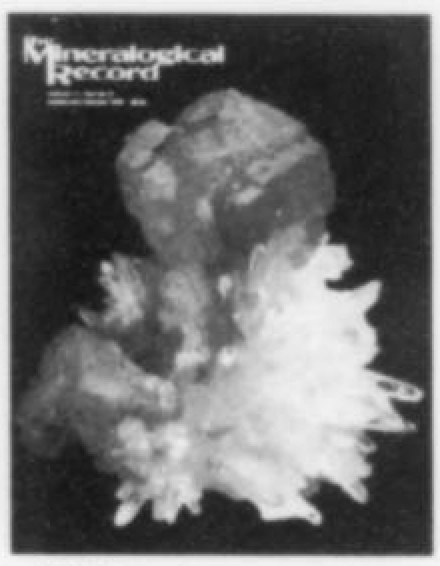
v.10/#2 Jeffrey mine (Quebec), Alpine Rodingites, Fluorite (Germany) **$10**

v.10/#3 Taewha mine (Korea) Japan Twins (Quartz), Bancroft (Ont.), Franklin **$10**

v.10/#5 Thomas & Wah Wah Ranges (Utah) (famous for Topaz, Red Beryl, etc) **$10**

v.11/#1 Toxic Minerals Barite from Hartsel (CO), Cassirer Memoirs (part II) **$10**

v.11/#2 Red Cloud mine (NM), Malachite (Australia, Uraninite, Kornerupine **$10**



v.11/#5 Los Lamentos (Mex.), Chromates (Iran), Nealite, Sperrylite, Mullica Hill **$10**

v.11/#6 Broken Hill (Zambia), Cruziero mine (Brazil), Caplan Interview, Rose Qtz. **$10**

v.12/#1 Iceland & Faeroes Zeolites, Yellowstone Zeolites **$10**

v.12/#3 Pribram (Czecho.), Bald Knob (NC), Line Pit (PA-MD), Mcguinnessite **$10**

v.12/#4 Mineral Fakes, Mineral Fraud, Leadhills-Wanlockhead (England) **$10**

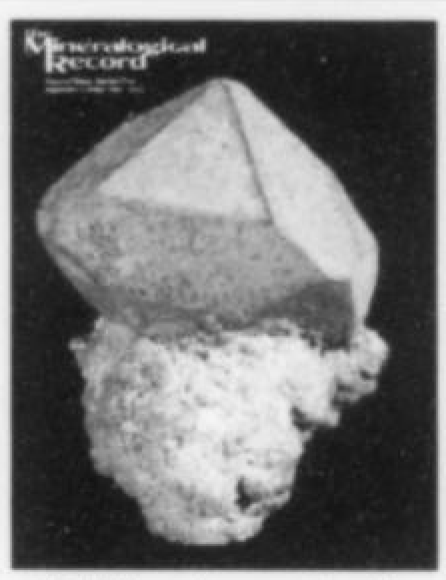
v.13/#4 Diamond (CO), Quartz (MT), Jeanbandyite, Bancroft (Ont.) **$10**

v.14/#1 Celestite (IN), Derbyshire (England), Lotharmeyerite (Mapimi) **$10**

v.14/#6 Chulquicamata (Chile), Univ. of Delaware Mineral Museum **$10**

v.15/#1 Darwin (CA), Pereta Mine (Italy), Cetine Mine (Italy) **$10**

v.15/#4 Sterling mine (NY), Burra mine (Australia), Lotharmeyerite, Jack Boyle **$10**



v.15/#5 Jacupiranga mine (Brazil), Jensen quarry (CA), Cunha Baixa mine, Paulkerrite **$10**

v.15/#6 Bad Ems (Germany), Touissit Vanadinite, Hawleyite (IN), Fluorapatite (SD) **$10**

v.16/#1 Nevada Issue! Comstock Lode, Getchell, Steamboat, Majuba Hill, White Caps **$10**

Postage $1 per copy– Order 10 copies or more and **we pay all postage.**

Supplies are Liminted

Circulation Manager
Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740

FAX YOUR CREDIT CARD ORDERS!
520-544-0815

MasterCard

VISA

BACK ISSUES!

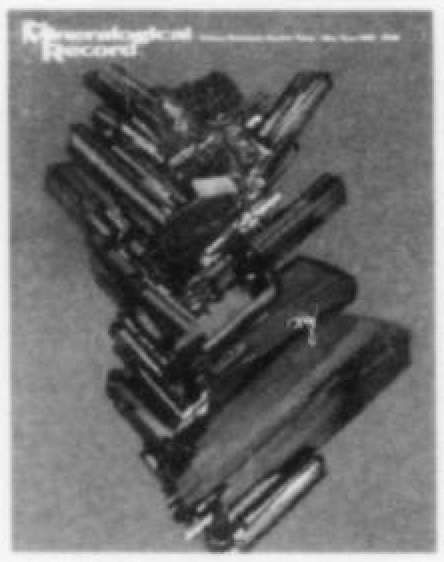
v.16/#3 Colorado-III Issue! Leadville, Rico, Cresson Vug, Pikes Peak, CSM Museum **$10**

v.16/#4 Kingsgate mines (Australia), Mauldin Mountain Phosphates (AL) **$10**

v.16/#5 Tourmaline Issue! (112 p.) Elba, Maine, Pakistan, Nepal, California, etc. **$15**

v.16/#6 Graves Mtn. (GA), Gardiner Complex (Greenland), Canaphite, Hutchinsonite **$10**

v.17/#2 J. C. Holmes claim (AZ), Austrian Minerals, Marsturite, Franklin (NJ) **$10**



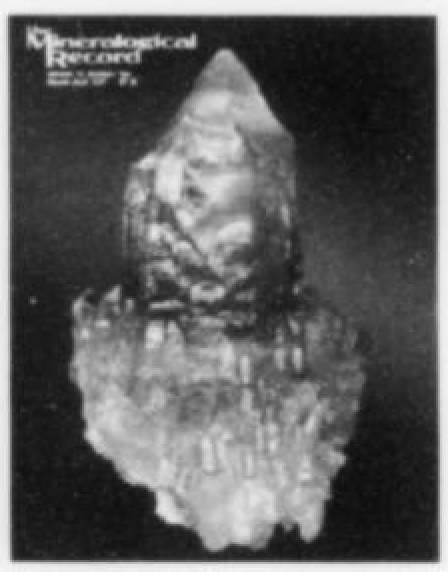
v.17/#3 Knappenwand (Austria), Laurium (Greece), Senaite (Brazil), Chalcophyllite (New Zealand) **$10**

v.17/#4 National Belle mine (CO), Tip Top mine (SD), Stoneham Barite (CO) **$10**

v.17/#5 Black Hills type localities, Urucum (Brazil), Kalkar quarry (CA), Kremsmünster **$10**

v.17/#6 Bleiberg (Austria), Brochantite (OK), Arsenopyrite (Ont.) Author's Guide **$10**

v.18/#1 Gold-II Issue! Australia, Calif., Breckenridge, Hopes Nose (England), etc. **$15**



v.18/#2 Elk Creek (SD), Teyler's Museum, Ramsbeckite, Neotocite, Phosphosiderite **$10**

v.18/#3 Uranium minerals (Sardinia), Garnet Hill (NV), Photographer's Guide, Library Guide **$10**

v.18/#4 Carrara Marble (Italy), Marburg Museum (Germany) **$10**

v.18/#5 Hale Creek Inesite (CA), Vanadium Minerals Review, Peking Museum **$10**

v.18/#6 Stereo Issue—Calcite, Pyrite, Morgan Hall (AMNH) **$10**

v.19/#1 Mineral Museums of Eastern Europe Full-color 72-page book-issue **$10**

v.19/#3 Table Mtn. Zeolites (CO), Tonopah-Belmont mine (AZ), Parker Cleaveland **$10**

v.19/#4 Ichinokawa mine (Japan), Bandora mine (CO), Chernikovite, Getchell arsenates (NV) **$10**

v.19/#5 Almaden (Spain), IMA, J. Berzelius, Probenite, Osarizawaite **$10**

v.19/#6 Australia Issue! 152 pages and much color photography! **$15**

Postage $1 per copy–Order 10 copies or more and **we pay all postage.**

Supplies are Liminted

Circulation Manager
Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740

FAX YOUR CREDIT CARD ORDERS!
520-544-0815

MasterCard VISA

BACK ISSUES!

v.20/#1 New Mexico Issue! 96 pages and much color photography! **$10**

v.20/#2 Little Three mine (CA), Zaragoza Gypsum (Spain), Calif. Locality Index **$10**

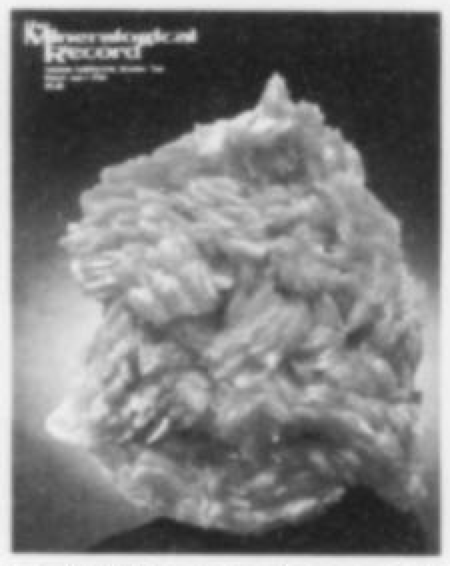
v.20/#3 Ouro Preto (Brazil), Anjanabonoina (Madagascar), Port Radium Silver (Canada) **$10**

v.20/#4 Katanga Uranium Issue! Shaba (Zaire) deposits, much color photography! **$10**

v.20/#5 Brazilian Diamonds, Leveäniemi mine Phosphates (Sweden), Phoenixville (PA) **$10**

v.20/#6 Spanish Pyrite, Pint's quarry (IA), Beaverdell (Br. Col.), Hollister (CA), Blue Ball (AZ) **$10**

v.21/#1 Special 20th Anniv. Issue! Roebling, Canfield, Bement, Paris Exp., Transylvania **$15**



v.21/#2 Thornberry Axinites (CA), El Dragón mine (Bolivia), Silver District (AZ), Goldschmidt **$10**

v.21/#3 American Amethyst Localities, Terlingua, Davis Hill, Edgarbaileyite, Faden Qtz. **$10**

v.21/#4 Mont Saint-Hilaire Issue! 112 pages and much color photography! **$15**

v.21/#5 Rose qtz. (Brazil), green Apatite (Brazil), stereo photogr., Carnegie Museum Catalog **$15**

Carnegie Museum Catalog Magnificent, 32-page, full-color catalog **free** in each v.21/#5.

v.21/#6 Nanisivik mine (Canada), De Kalb (NY), Murfreesboro (AR) Australian Diamonds **$10**

v.22/#1 Mashamba mine (Zaire), Fat Jack mine (AZ), Monitor-Mogul (NV), azurite, Scandinavia **$10**

v.22/#2 Mezica mine (Yugoslavia), Caldbeck Fells (England), SEM, Eugui quarries (Spain) **$10**

v.22/#3 Messina mines (So. Afr.), Idria mines (Yugoslavia), Outlaw mine (NV), Pribram (Czech.) **$10**

v.22/#4 Kalahari update (So. Afr.), Seriphos (Greece), Lake George mine (New Bruns) **$10**

v.22/#5 Smokey Bear qtz. (NM), Taaffeite, Sterling Hill (NJ), Grew's *Mus. Reg. Soc.* (1681) **$10**

v.22/#6 Wagholi cavansite (India), Kombat mine (Namibia), Madan mines (Bulgaria), Beltana mine **$10**

v.23/#1 Dohrmann Gold collection, Gillette quarry (CT), Spanish fluorite **$15**

Postage $1 per copy–Order 10 copies or more and **we pay all postage.**

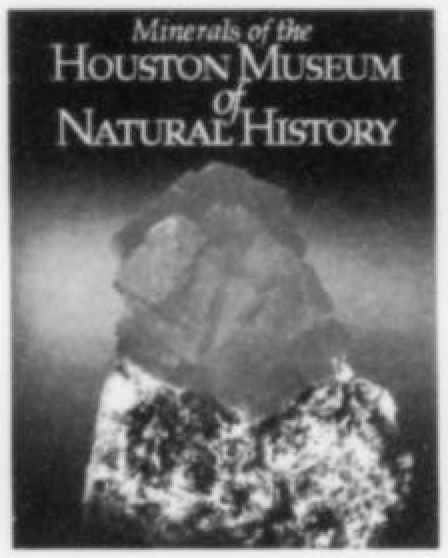
Supplies are Liminted

Circulation Manager
Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740

FAX YOUR CREDIT CARD ORDERS!
520-544-0815

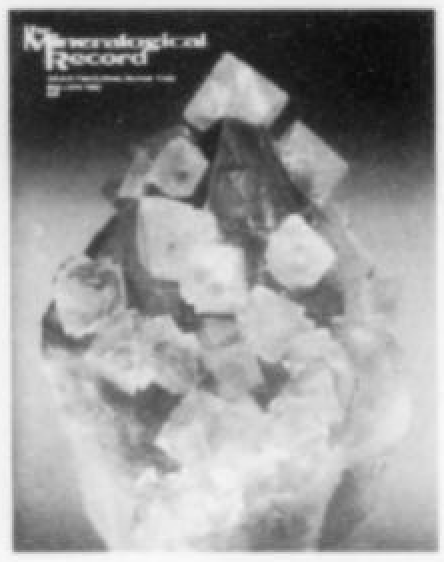
MasterCard VISA

BACK ISSUES!



Houston Museum Catalog Magnificent, 32-page, full-color catalog **free** in each v.23/#1

v.23/#2 Michigan Copper Country Issue! Spectacular, 104-pg book issue. One of our best! **$15**

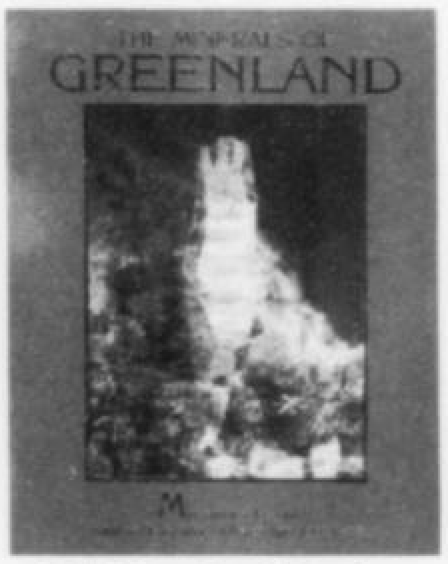


v.23/#3 African gold, Iowa calcite, Hiendelaencina (Spain), Freiberg Acad.; Tucson & Paris Shows **$10**

v.23/#4 Yukon Phosphates Issue! The only complete review of these famous occurrences **$10**

v.23/#5 Matlock (England), Prenleg (Wales), Stephen Smale Collection, Mineral Stories **$10**

v.23/#6 Apatite (Que.), Palladium & Platinum (Brazil), Black Pine mine (MT), Franklinphilite **$10**



v.24/#2 Greenland Issue! Spectacular 88-page full-color book issue. **$15**

v.24/#3 Majuba Hill (NV), Sawtooth Batholith (ID), Ashburton Downs (Aust.), 1992 Shows **$10**

v.24/#4 Cornwall (England), Rush Creek (AR), Clinomimetite (New Mineral) **$10**

v.24/#5 The Geysers (CA), Sanford (ME), Wessels mine (So. Afr.), Parker mine (Que.) **$10**

v.24/#6 Bisbee Update (AZ), Allchar (Macedonia), Calcite xls, Seelite & Edoylerite **$10**

v.25/#1 Gold (CA), Horcajo mines (Spain), Zomba (Malawi), Matlock (Scotland), Silver Symposium **$10**

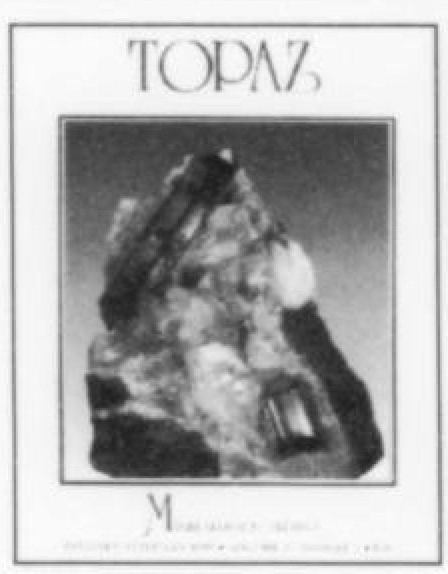
v.25/#2 Quasicrystals, French Creek (PA), Burra Burra mine (Austral.) Sterling mine (NJ) **$10**

v.25/#3 Jaguaraçu Peg. (Brazil), Bennet Peg. (ME), Prospect Int. (Austral.), Rose mine (NM) **$10**

v.25/#4 Blowpipe Analysis, Laurium (Greece), Widgiemooltha (Australia) **$10**

v.25/#5 Oreford mine (Que.), Martin Ehrmann, Ouray Co. (CO) **$10**

v.25/#6 History of Mineral Collecting 1530–1799, Giant 264 p. Full-Color Issue! **$24**



v.26/#1 Topaz Issue! Worldwide mineralogy, Localities, Symposium **$10**

v.26/#2 Hopkinton Amethyst (RI), Sinhalite (Ceylon), Mrazekite (Austral.), Pyrite **$10**

v.26/#3 Kipushi mine (Zaire), Bolivian Death Switch, Microminerals **$10**

Postage $1 per copy– Order 10 copies or more and **we pay all postage.**

Supplies are Limited

Circulation Manager
Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740

FAX YOUR CREDIT CARD ORDERS!
520-544-0815

MasterCard VISA

The Friends of Mineralogy

Who We Are:

Vol 1, No 1, Mineralogical Record, Spring 1970
The *Friends of Mineralogy* was founded in Tucson, Arizona, on February 13, 1970. Its objectives were to promote better mineral appreciation, education and preservation. The chief aims and activities of *FM* include:

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

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

Co-Sponsor, with the Tucson Gem & Mineral Society and the Mineralogical Society of America, of the Annual Tucson Mineralogical Symposia.

Pacific Northwest Chapter: For information about the Pacific Northwest chapter contact Wes Gannaway, President, 1604 Brookwood Dr., Ferndale, WA 98248; 206-384-4209

Pennsylvania Chapter: *Reminiscences of a Mineralogist,* by Arthur Montgomery. Order from: Friends of Mineralogy, PA Chapter.

For information about the Pennsylvania chapter contact: Roland Bounds, 315 Stamford Dr., Newark, DE 19711-2723; 302-731-8407

Southern California Chapter: For information contact: Bob Reynolds, President, 2024 Orange Tree Lane, Redlands, CA 92374-2850; 909-798-8570

NOTE! Enter the **Werner Lieber Photo Contest!** Sponsored by FM: A traveling museum exhibit will be created from the best entries. *Categories:* Junior, Adult Amateur, Professional, and Digital or Computer-Enhanced. Submit 8x10 print in 11x14 matte, fully captioned, of a MEXICAN mineral. Submission Deadline: NOVEMBER 1, 1998. Mail to: Dr. Karen Wenrich, P.O. Box 5054, Golden, CO 80401 (for info contact Karen at (303) 278-1218 or at CrystalsUL@aol.com).

Chapter News:

Colorado Chapter: Order Now!! Minerals of Colorado.
Order from: Friends of Mineralogy—Colorado Chapter,
P.O. Box 11005, Denver, CO 80211-0005
$150 + $3 p.&h. (Colo. residents add 7.3%)

For information about the Colorado chapter contact: Bill Chirnside, 2157 S. Cole Ct., Lakewood, CO 80228; 303-989-8748

Great Basin Chapter: For information about the Great Basin chapter contact: Jim Abbot, Highroller@hotmail.com

Midwest Chapter: Visit out Web page at: www.indiana.edu/~minerals

For information about the Midwest chapter contact: Dr. Henry Barwood, President, Indiana Geological Survey, 611 N. Walnut Grove, S-409-A, Bloomington, IN 47405

1998 Officers:

President:
Nelson Shaffer, 530 Cabot Ct., Bloomington, IN 47408
(812) 855-2687 e-mail: shaffern@indiana.edu

Vice-President:
Susan Eriksson, Geology Dept., Virginia Tech, Blacksburg, VA 24061
(540) 231-5360

Secretary:
Mike Howard, 3815 W. Roosevelt Rd., Little Rock, AR 72204
(501) 296-1877 e-mail: JMichaelH@aol.com

Treasurer:
Roland Bounds, 315 Stamford Dr., Newark, DE 19711-2723
(302) 731-8407 e-mail: 25628@UDel.Edu

For Membership Information Contact:

Membership Chair:
Regina Modreski, 8075 W. Freemont Dr., Littleton, CO 80123-4315

Treasurer:
Roland Bounds, 315 Stamford Dr., Newark, DE 19711-2723
(302) 731-8407 e-mail: 25628@UDel.Edu

Newsletter Editors:
Credo Schwab, 4701 W. San Rafael St., Tampa, FL 33629
Mike Howard, 3815 W. Roosevelt Rd., Little Rock, AR 72204

THE MUSEUM DIRECTORY

Geology and Meteorite Museums University of New Mexico
Curators: Gary Smith (Geology)
Adrian Brearley (Meteorites)
Tel: (505) 277-4204
Dept. of Earth & Planetary Sciences
Northrop Hall, Univ. of New Mexico
Albuquerque, NM 87131
Hours: 9–4 M–F (closed on school holidays)
Specialties: Worldwide minerals and meteorites, New Mexico fossils, Harding Pegmatite Mine Collection

Colburn Gem & Mineral Museum
Executive Director: Rebecca Lamb
Curator: Susan Granados
Tel: (704) 254-7162
Fax: (704) 251-5652
Pack Place Education, Arts & Science Center
2 South Pack Square
Asheville, NC 28801
Hours: 10–5 Tues.–Sat. (all year); 1–5 Sun. (June–Oct.); Closed Mondays and holidays
Specialties: North Carolina and worldwide minerals and gems
Accessible to persons with disabilities

Montana Tech Mineral Museum
Curator: Richard Berg
Adjunct Curator: Lester G. Zeihen
Tel: (406) 496-4414
c/o Montana Tech
Butte, MT 59701-8997
Hours: 9–6 daily June–Labor Day; 9–4 Weekdays Labor Day–May
Specialties: Montana & Idaho minerals; systematics

Museums listed alphabetically by city

Harvard Mineralogical Museum
Curators: Dr. Carl A. Francis
William Metropolis
Tel: (617) 495-4758
24 Oxford Street
Cambridge, Mass. 02138
Hours: 9–4:30 M–Sat.; 1–4:30 Sun.
Specialties: Systematic Mineral Collection

William Weinman Mineral Museum
Asst. Curator: Doug Gravely
Tel: (770) 386-0576
51 Mineral Museum Dr.
White, GA 30184
Hours: 10–4:30 Tues.–Sat., 2–4:30 Sun.
Specialty: Georgia & worldwide minerals & fossils

Western Museum of Mining & Industry
Curator: Terry A. Girouard
Tel: (719) 495-2182
Telnet pac.ppld.ord (Library Cat.)
Dir. of Educ.: Eric L. Clements
Tel: (719) 488-0880
Fax: (719) 488-9261
www.wmmi.org
1025 North Gate Road
Colorado Springs, CO 80921
Hours: 9–4 M-Sat., (12-4 Sun., June–Sept. only), closed holidays
Specialties: Colorado minerals & ores, Western mining equip. & memorabilia, 11,000-vol. research library

Denver Museum of Natural History
Curator of Geology: Jack A. Murphy
Tel: (303) 370-6445
Dept. of Earth Sciences
20001 Colorado Blvd.
Denver, CO 80205
Hours: 9–5 daily
Specialties: Colorado minerals

Geology Museum Colorado School of Mines
Curator: Virginia A. Mast
Tel: (303) 273-3823
Golden, Colorado 80401
Hours: 9–4 M–Sat., 1–4 Sun. (closed on school holidays & Sundays in the summer)
Specialties: Worldwide minerals; Colorado mining & minerals

A. E. Seaman Mineralogical Museum
Curator (mineralogy): George W. Robinson
Adjunct Curator: Dr. John A. Jaszczak
Tel: (906) 487-2572
Michigan Technological Univ.
Houghton, Michigan 49931
Hours: 9–4:30 M–F
Specialty: Michigan minerals, copper minerals & worldwide minerals

Houston Museum of Natural Science
Curator (mineralogy): Joel Bartsch
Tel: (713) 639-4673
Fax: (713) 523-4125
1 Herman Circle Drive
Houston, Texas 77030
Hours: 9–6 M–Sat., 12–6 Sun.
Specialty: Finest or near-finest known specimens

THE MUSEUM DIRECTORY

Natural History Museum of Los Angeles County
Curator (Mineral Sciences):
Dr. Anthony R. Kampf
Tel: (213) 763-3328
Collections Manager:
Dorothy L. Ettensohn
Tel: (213) 763-3327
Fax: (213) 749-4107
900 Exposition Blvd.
Los Angeles, CA 90007
Hours: 10–4:45 Tues.–Sun.
Specialties: Calif. & worldwide minerals, gold, gem crystals, colored gemstones
Support organization:
The Gem and Mineral Council
Website: http://nhm.org/~gmc

University of Delaware Mineralogical Museum
Curator: Dr. Peter B. Leavens
Tel: (302) 831-8106
E-Mail:
PBL@BRAHMS.UDEL.EDU
Department of Geology
University of Delaware
Newark, DE 19716
Hours: 8:30–4:30 M–F
Specialty: Worldwide minerals

Carnegie Museum of Natural History
Collection Manager: Marc L. Wilson
Tel: (412) 622-3391
4400 Forbes Avenue
Pittsburgh, PA 15213
Hours: 10–5 Tues.–Sat.,
10–9 F, 1–5 Sun.,
closed Mon. & holidays
Specialty: Worldwide minerals & gems

Museum of Geology
Director: Philip R. Bjork
Tel: (605) 394-2467
South Dakota School of Mines & Technology
501 E. St. Joseph Street
Rapid City, SD 57701-3995
Hours: 8–5 M–F, 9–4 Sat., 1–4 Sun.
Specialty: Black Hills minerals, esp. pegmatites

New Mexico Bureau of Mines & Mineral Resources—Mineral Museum
Director: Dr. Virgil W. Lueth
Tel: (505) 835-5140
E-Mail: vwlueth@nmt.edu
Fax: (505) 835-6333
Assistant Curator: Lynn Heizler
Tel: (505) 835-5166
New Mexico Tech
801 Leroy Place
Socorro, NM 87801
Hours: 8–5 M–F, 10–3 Sat., Sun
Specialties: New Mexico minerals, mining artifacts, worldwide minerals

Penn State Earth & Mineral Sciences Museum
Curator: Andrew Sicree
Tel: (814) 865-6427
E-mail: sicree@geosc.psu.edu
Steidle Building
University Park
State College, PA 16802
Hours: 9–5 M–F & by Appt.
(closed holidays)
Specialties: Mineral properties exhibits; "velvet" malachite; old Penna. minerals, mining art

Arizona-Sonora Desert Museum
Collections Manager & Mineralogist: Anna M. Domitrovic
Tel: (520) 883-3033
Fax: (520) 883-1380 ext. 152
2021 N. Kinney Road
Tucson, AZ 85743-8918
Hours: 8:30-5 Daily (Oct.-Feb.)
7:30-6 Daily (Mar.-Sept.)
Specialty: Arizona minerals

Europe

Giazotto Mineralogical Museum
Curator: Adalberto Giazotto
Tel: 39-50-501587
Lungarno Gambacorti 39
Pisa, Italy
Hours: by Appointment
Specialty: Italian and Worldwide minerals

THE

ULTIMATE REFERENCE!

to a Quarter-Century of Mineralogy & Mineral Collecting:

$35 + $3 shipping
312 pages, $8^{1}/_{4}$ x 11 inches

The

25-YEAR INDEX

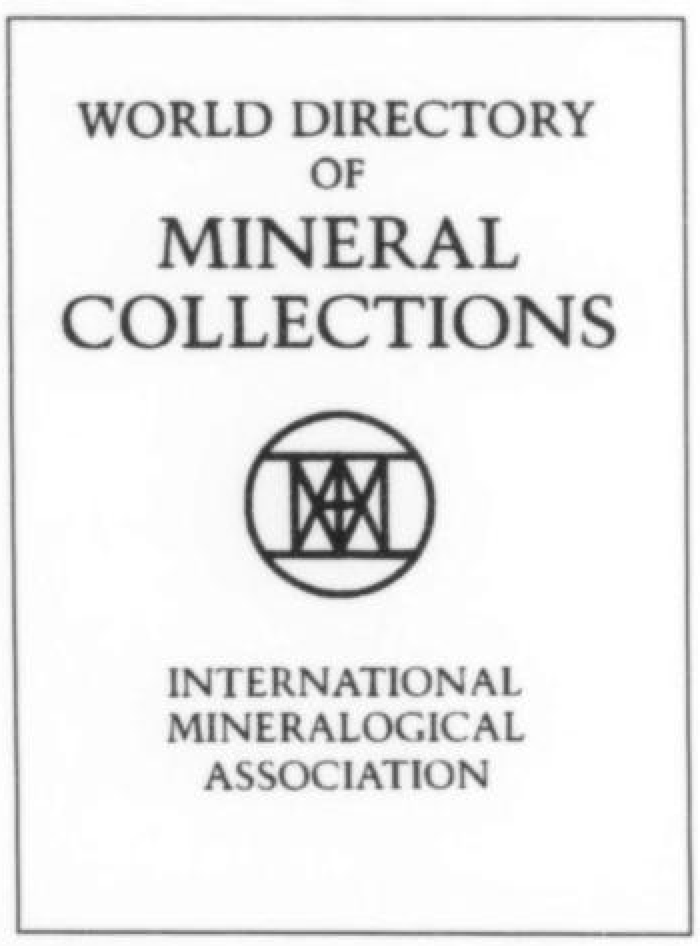
To The

MINERALOGICAL RECORD

by Edwin L. Clopton
& Wendell E. Wilson

Bound Hardcover with a sewn binding to withstand years of heavy use!
Whether you own a complete set of issues or not, this is one reference you *cannot afford* to be without.
Credit Card orders (VISA or MC) accepted by FAX. Order now!

Available Only From:
The Mineralogical Record
P.O. Box 35565, Tucson, AZ 85740 • 520-297-6709 • **FAX 520-544-0815**



$16 plus $2 postage

ORDER FROM
The Mineralogical Record
P. O. Box 35565
Tucson, AZ 85715

ESSENTIAL REFERENCE!

World Directory of Mineral Collections

by the
International Mineralogical Association

Provides essential data on 444 mineral museums in the United States and 31 foreign countries, including history, staff, address, phone and fax numbers, size and orientation of the collection, services provided, hours open, etc. Arranged geographically for easy reference when traveling.

CREDIT CARD ORDERS (VISA, MC) ACCEPTED; FAX ORDERS ACCEPTED, FAX 520-544-0815

Mineralogical Record

Antiquarian Reprints

Since 1990 the Mineralogical Record has been producing hand-made limited-edition reprints of some of the rarest and most sought-after antiquarian color-plate mineral books. Each edition has sold out quickly and become a collector's item in its own right. These beautiful and interesting works make fascinating and useful additions to any library. People on our mailing list receive **advance notice** of each new edition by mail. A place on our list is yours for the asking . . .

GET ON OUR MAILING LIST!
The Mineralogical Record
4631 Paseo Tubutama
Tucson, AZ 85715
Tel.: (520) 299-5274 • FAX: (520) 299-5702

No. 1 Schmiedel's *Erz Stuffen und Berg Arten* (1753) with 46 color plates. $200 [SOLD OUT]

No. 2 Hebenstreit's *Museum Richterianum* (1743) with 14 color plates. $250 [SOLD OUT]

No. 3 Grew's *Musaeum Regalis Societatis* (1681) plus De Boate's *Rare and Excellent Discourse on Minerals* (1653) $100 (no color) [SOLD OUT]

No. 4 Gautier d'Agoty's *Histoire Naturelle Regne Mineral* (1781) with 78 color plates. $325 [SOLD OUT]

No. 5 Stieglitz's *Spicilegium quarundam rerum naturalium subterraneorum* (1769) with 22 color plates and a *full English translation*. $170 [SOLD OUT]

No. 6 Sowerby's *Exotic Mineralogy* (1811), vol. 1, with 100 color plates. All text in English. $375 [SOLD OUT]

No. 7 Sowerby's *Exotic Mineralogy* (1817), vol. 2, with 69 color plates. All text in English. $345 [SOLD OUT]

No. 8 Rashleigh's *Specimens of British Minerals* (1797 and 1802), vols. 1 and 2 combined, plus new portrait and introduction; 233 specimens illustrated in color. $310 [SOLD OUT]

No. 9 J. G. Lenz's *Mustertafeln der bis jetzt bekannter einfachen Mineralien* (1794), with color illustrations of 366 specimens from the collection of the Grand Duke of Saxe-Weimar. $280 [SOLD OUT]

No. 10 Wulfen's famous monograph on wulfenite, *Abhandlung vom kärnthnerischen Bleyspate*; includes new English introduction and biography, all 21 color plates reproduced, along with full text of the 1785 and 1791 editions; English translation of Wulfen's 1785 introduction plus Kunitsch's rare 1810 biography and an English chapter on Wulfen's wulfenite locality, Bleiberg, Austria. Calfskin spine. $290 ppd in U.S. (+$10 outside the U.S.), WHILE SUPPLY LASTS.

Limited Editions!

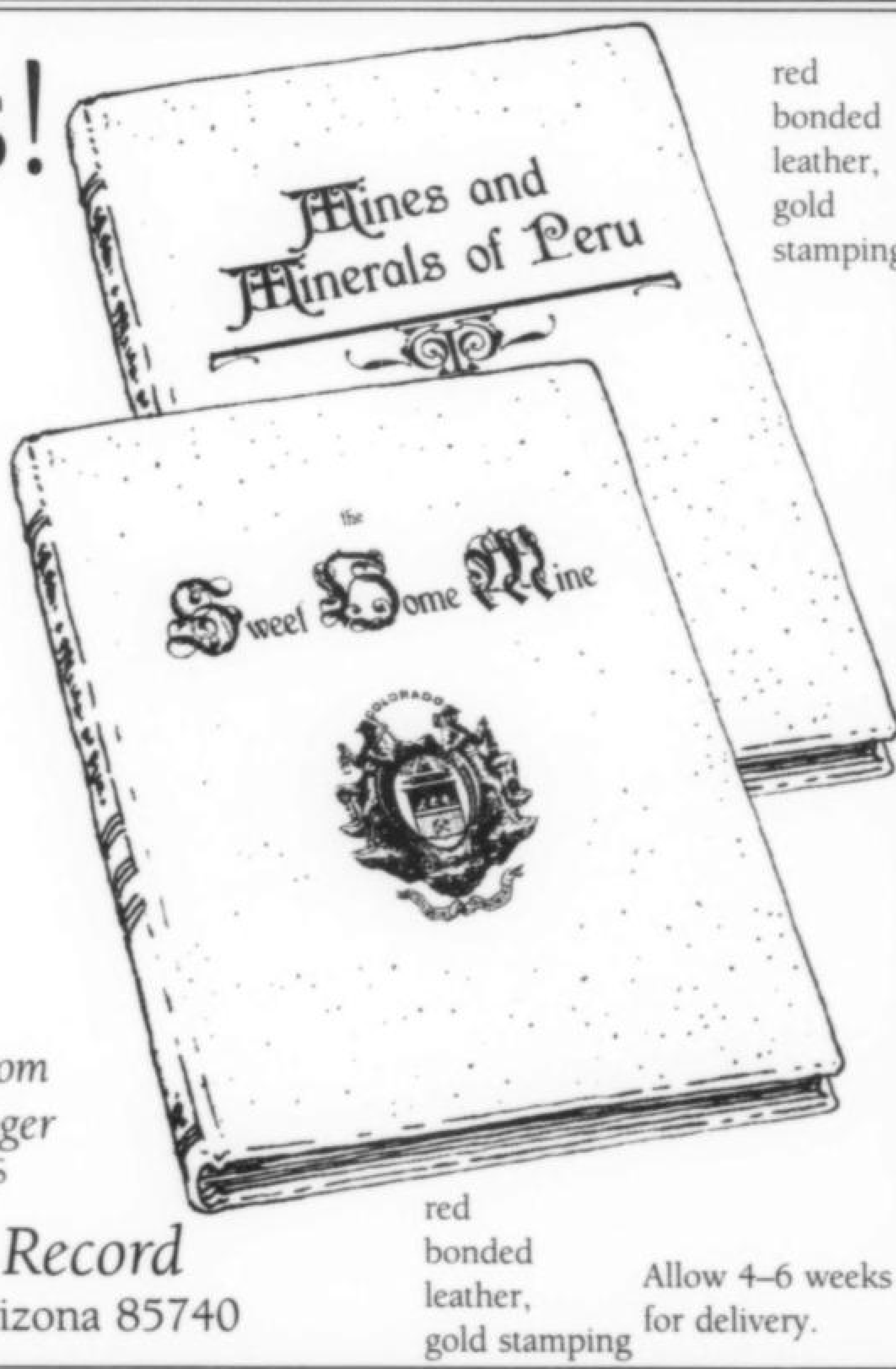
LEATHER-BOUND EDITIONS

MINES AND MINERALS OF PERU

$49 plus $1 postage (U.S. & Can.)
(foreign orders add $1)

THE SWEET HOME MINE

192 pages with over 200 color illustrations!
$49 plus $1 postage (U.S. & Can.)
(foreign orders add $1)



red bonded leather, gold stamping

red bonded leather, gold stamping

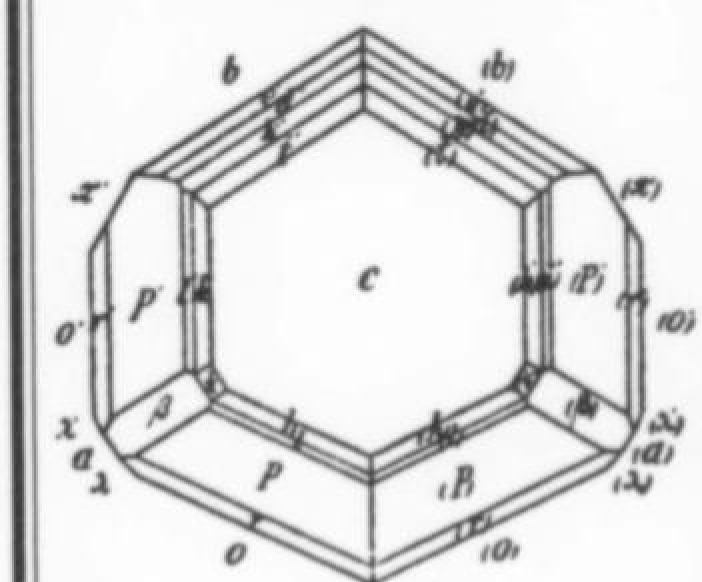
these are available from the Circulation Manager
WHILE SUPPLY LASTS

FAX YOUR CREDIT CARD ORDER!
520-544-0815

MasterCard VISA

The Mineralogical Record
P.O. Box 35565 • Tucson, Arizona 85740

Allow 4–6 weeks for delivery.



Volunteer Coordinators
Eastern U.S.
Charles & Marcelle Weber
1172 West Lake Ave.
Guilford, CT 06437

Advertising Information
All advertising in the Mineralogical Record must be paid in advance of the closing date. Telephone orders not accepted. Write to the editor for rates.

Closing dates:

Jan.-Feb. issue	Oct. 15
March-April issue	Dec. 15
May-June issue	Feb. 15
July-Aug. issue	April 15
Sept.-Oct. issue	June 15
Nov.-Dec. issue	Aug. 15

An additional 20 days past the closing date are allowed in which advertisers may make changes (excluding size changes) in ads already paid for.

Design
Wendell E. Wilson

Graphic Production
Capitol Communications
Crofton, MD

Printing
Cadmus Journal Services,
Easton, MD

Color Separations
Hollis Phototechnics
Tucson, AZ

Circulation
P.O. Box 35565
Tucson, AZ 85740
520-297-6709

Editing, advertising
4631 Paseo Tubutama
Tucson, AZ 85750
520-299-5274

Foreign Payments
Remittance may be made in local currency, at *prevailing exchange rates*, without surcharge, to the following people:

Belgium
Paul Van Hee
Marialei 43
B-2900 Schoten

Canada
Mrs. J. W. Peat
36 Deepwood Crescent
Don Mills, Ontario M3C 1N8

Great Britain
Paul Lowe
"Endsleigh"
50 Daniell Road
Truro, Cornwall TR1 2DA

Italy
Renato & Adriana Pagano
P.O. Box 37
I-20092 Cinisello Balsamo MI

Japan
Bon Earth Sciences
Tsukasa Kikuchi
Nagata Bldg. 201
19-10 Kitaotsuka 2-chome
Toshima, Tokyo 170

Netherlands
W. J. R. Kwak
Kabeljauwallee 23
6865 BL Doorwerth (Gld)

Norway & Sweden
Geir Wiik
N-2740 Roa
Norway

South Africa
Horst Windisch
30 Van Wouw Street
Groenkloof, Pretoria

Germany
Christian Weise Verlag
Oberanger 6
D-80331 München 2

Affiliated with the Friends of Mineralogy, an independent, non-profit organization devoted to furthering amateur and professional interests in mineralogy. For membership information contact Roland Bounds, Treasurer 315 Stamford Drive, Newark, DE 19711-2723

Opinions expressed are those of the authors and do not necessarily reflect those of the Mineralogical Record Inc., its editorial staff or directors.

Advertisers Index