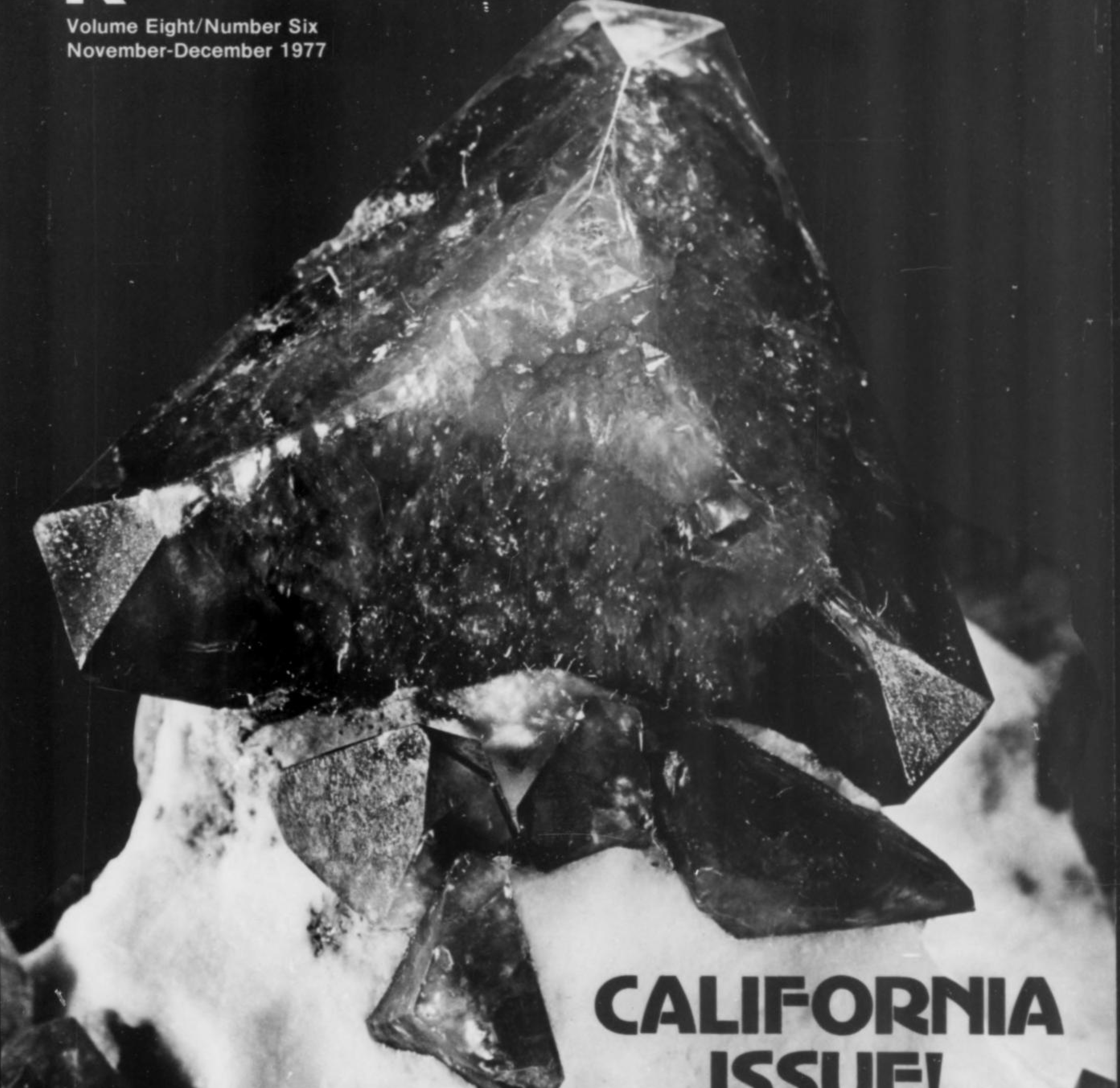
the Mineralogical Record

Volume Eight/Number Six
November-December 1977



CALIFORNIA ISSUE!

$5.

SHOWS

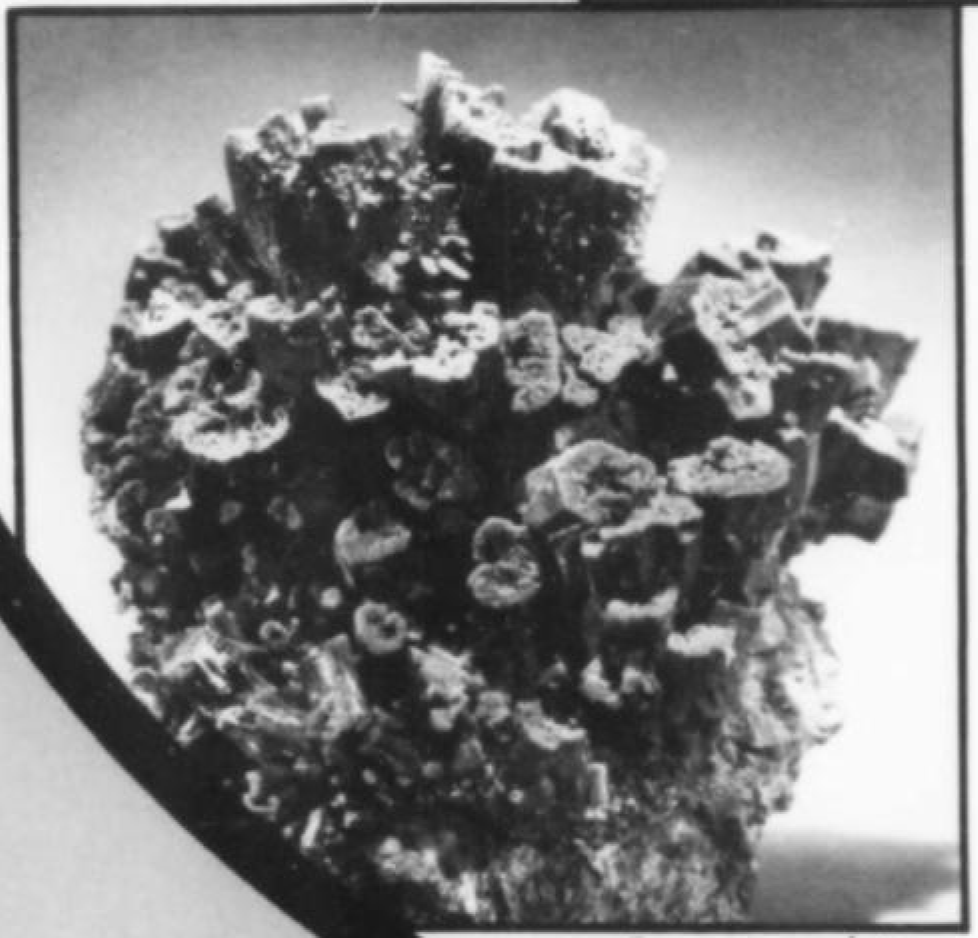
Pasadena - Nov. 19-20

Tucson - February 10-12

Tourmaline-
Golconda mine,
Minas Gerais, Brazil

Sulfur-
Perticara, Romagna, Italy

specimens
subject to
prior sale



Pyromorphite-
Wheatley mine,
Phoenixville,
Pa.

Hours: Wed-Sat. 10-5
Sunday 12-5 [evenings
by appointment only]

KRISTALLE

Wayne and Dona Leicht, 332 Forest Ave. #8, Laguna Beach, Cal. 92651 [714]494-7695

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THE MINERALOGICAL RECORD

VOLUME EIGHT, NUMBER SIX

NOVEMBER-DECEMBER 1977

CALIFORNIA ISSUE

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COVER: BENITOITE with natrolite, from the Benitoite Gem mine, San Benito Co., California. The main, "triply terminated" crystal measures about 3 cm across. This specimen is regarded by many as the finest benitoite in existence; it was donated to the California Federation of Mineral Societies by David Wilber, on July 3, 1976. Photo by Harold and Erica Van Pelt, Photographers, Los Angeles.

Including
many fine
Photographs
by
Harold and Erica Van Pelt
Photographers, Los Angeles

GUEST EDITORIAL

Helping the New Collectors

by David Eidahl*

THE guest editorial by Marie Huizing which appeared in the Pegmatite issue ("I am curious (and) green") dealt very effectively with the many ways a new mineral collector can help himself (or herself) advance. But why should the already advanced collectors, dealers and mineralogists help these new collectors along on their way? One might at first be tempted to view these rising enthusiasts as either (a) insignificant, or (b) potential future competition for a limited supply of minerals. Both of these views are shortsighted. Assisting new collectors now will help them take their place as contributing members of the mineral fraternity in the future. Rather than being competition, these new collectors may be the ones to discover new deposits or help to import new discoveries from which everyone will benefit. As they rise in purchasing power they will support a broad spectrum of the mineral market, everything from 30¢ cleavage fragments and inexpensive but representative species examples to fine display pieces with which they can demonstrate their personal tastes and values. The mineral market needs new collectors to maintain its current vitality; when dealers can no longer afford to travel the world searching out fine minerals, every collector will suffer. The new collector is indeed significant.

But there are a number of hindrances currently operating against the new collector. Advanced collectors, dealers and researchers as a whole tend to ignore young collectors completely. The advanced collector cannot see him as an equal and a colleague; the dealer knows he has little money, and will tend to dote on the better funded collectors; many researchers are disdainful of even the *advanced* collector and can hardly ever be bothered by the novice. Before we ignore young collectors we should think back to our own beginnings. Where would we be if certain people had not given *us* the needed help and encouragement? We were all novices once. Would it not be nice someday to be remembered by one of tomorrow's great collectors or scientists as the person who gave him his start when he was but a youngster? By helping the young we become part of the unbroken chain of enlightenment that will preserve and advance the study of minerals through untold future centuries.

Another hindrance to the new collector is high prices. This is very difficult to combat directly, since we can hardly expect a dealer to sell a $1000 specimen to a young collector for $10 simply because he can't afford more. However, giving an occasional discount to the beginner, especially if it is on an inexpensive specimen to begin with, would be a wise policy.

A third detrimental influence is the setting of bad examples. What is a new collector to think when he sees dealers degrading each other's specimens or, worse yet, each other? Rivalries nearly as intense can arise between collectors as well, and young collectors are often exposed to a plethora of unethical practices carried out with glee.

What, then, is to be done to counter these negative influences? Experienced collectors should be the beginner's first line of defense. Taken under their wing, he can be exposed to the endless variety of minerals in private collections; he can be guided and taught the basics on which he will be able to build. If money is a problem (as it usually is) he can be introduced to field collecting and trading. He can be shown that the very inexpensive specimens have their place and can give great enjoyment and knowledge. He can be encouraged to collect what interests *him*, regardless of what interests others. Perhaps he will eventually take up the serious study of mineralogy and one day rejoice at being able to earn a living doing what he would have done for a hobby anyway...study minerals!

Most young collectors are intimidated by dealers. The dealers, however, will find it in their best interest to pay some friendly attention to the young collectors. They should look at it as an investment in the future. If the young collector of today becomes the suspicious, uneducated, disenchanted collector of tomorrow, what will happen to the mineral market? The dealer who simply *enjoys* helping young collectors receives his own rewards and hardly needs to be tempted with money; but such friendly and philanthropic people are not as common as one might wish. The suggestion here is to help young collectors even if you don't make a buck on the deal immediately; you will eventually benefit in one way or another. Some of today's young collectors will be tomorrow's *major* collectors, and they'll remember how they were treated, and by whom.

Museums are excellent places for new collectors to see and learn. Curators should make a special effort to provide some displays on the basics that are easy to understand. Displays which are low enough for children to see (as in the American Museum) and displays which allow viewers to *touch* the specimens too (also found in the American Museum) are particularly valuable. Museums present a fine opportunity for the experienced collector to take a novice friend for a tour, answering questions and explaining the many interesting details that cannot be included on short museum labels.

Self-collecting is where many beginners begin. Here it is especially valuable to have an experienced friend...one who knows the local mineral occurrences and can take the beginner along on field trips. Gem and mineral clubs are especially valuable to the new collector; he is exposed to many experienced collectors and can take part in club field trips. In parts of the country where underground collecting is practiced it is essential for the beginner to have an experienced companion.

Mineral shows provide another unique opportunity for the beginner. If the show committee has arranged for and encouraged novice exhibits as well as educational exhibits by more sophisticated collectors the beginner can learn by presenting his own exhibit as well as by seeing those of others. On set-up day he can chat with the other exhibitors (the friendly ones, at least) and compare notes.

The sum of this discussion is the point that beginners and experienced collectors need each other. The new collector, given friendship, indulgence and help, becomes in later years the valued colleague, the contributor to the hobby and the science, and the supporter of the mineral market that we all need. The moral: whether you are a collector, curator or dealer, take the beginners under your wing. You'll be doing them, yourself, and all the rest of us a favor.

***912 S. Live Oak Park Road, Fallbrook, California 92028**

NOTES FROM THE EDITOR

Welcome to our *California Issue*! This special issue began to take shape about a year ago when several articles on California localities came in within a short period of time. With those articles as a base, more were solicited and appropriately fine photography (much of it the superb work of professional photographers Harold and Erica Van Pelt of Los Angeles) was sought until a sufficiently large body of work had been accumulated to fill an issue and then some. Of course we make no claim to a *complete* coverage of California mineralogy and localities...that would require volumes. Similarly, our *Europe Issue* did not pretend to cover all of Europe, nor our *Pegmatite Issue* all pegmatites. Only with the Tsumeb issue was an approach to completeness attempted. But this issue on California does contain some significant and interesting contributions. Most special issues in the future will be created in a similar fashion, although a few will undoubtedly be conceived in their entirety before any writing is done. Because most special issues do not cover their topic completely there is always the possibility of Colorado, Pegmatite, Europe and California issues number two, three, four, etc., depending upon the articles we receive and are able to solicit. Special issues present special problems, the most difficult of which are deciding on the scope of the issues and obtaining solicited articles in a period of months rather than years. Suggestions for topics for special issues are always welcome.

Suggestions for specific articles are also welcome. If you think a particular locality, mineral or mineral-related topic would make an interesting article for the *Record*, let us know. The article on the characterization of new minerals by Pete Dunn in the last issue (vol. 8, no. 5) was first suggested by Janet Cares of Sudbury, Massachusetts; she also suggested that Pete would be an excellent choice to author such an article. I agreed, suggested the idea to Pete, and the rest, as they say, is history. The article on twinning in the same issue was suggested by several people independently, and if such an article had not already been in preparation at the time of the suggestions, one would certainly have been solicited. When making a suggestion for an article, please feel free to suggest possible authors who might be best qualified to write it. If your suggestion sounds like it would interest a fair share of our readers, and an author can be found to write such an article, your idea will eventually materialize in these pages for the enjoyment of all. I feel this method of generating articles has tremendous advantages: (1) you can influence the *Record* toward publishing what you want to read...which, after all, is the primary function of the *Record*. It is hardly worthwhile for us to publish what you *won't* read. (2) We can choose, with your help perhaps, the *most* qualified author, thereby increasing the quality of what we publish. (3) Readers can come up with some very innovative ideas which the editorial staff might not have thought of. I have a file labelled "suggested articles," and you are all invited to add to it.

An issue perhaps as large as the Tsumeb issue is being assembled on *Pegmatites of Minas Gerais* and their minerals. Already completed for this issue are articles on Virgem da Lapa and on herderite (a comprehensive article including chemistry, morphology, and some surprising nomenclature). Articles appropriate for any of these issues, especially the latter, are enthusiastically solicited. Potential authors are encouraged to write to me about their ideas.

Another subject of continuing interest is the series of articles dealing with *Famous Mineral Localities*. Again, this is an area in which we are seeking papers. Locality articles have always been a mainstay of the *Record*, and articles on famous localities are of special interest.

Readers will notice another new column in this issue: *Microminerals* by Violet Anderson. Our 1973 survey revealed that nearly a fifth of our readers are micromounters...a group too large and enthusiastic to be neglected for long. Therefore I have asked Vi to stand in for Neal Yedlin while he is recuperating from his illness. Vi is one of Canada's foremost micromounters and is a specialist in micromount photography. Rather than duplicating Neal's approach she will be doing her own thing, and it should be interesting. Readers with newsworthy micromounting information are urged to write to her.

The funds required to produce color in this issue were graciously donated by our long-time benefactor, Randy Rothschild, and by Forrest Cureton (one of our advertisers). Any donation to the *Record* is now **fully tax-deductable**; we have recently been granted status as a non-profit organization. The end of the fiscal year is coming soon, and if your tax accountant says you need to make some tax-free donations to stay in a lower tax bracket, keep the *Record* in mind...100% of such donations are used for more pages and more color because our administrative costs are already secure. Very few non-profit organizations can make that claim.

A note to dealers, especially those of you in California: not many people are aware that the *Record* is available to dealers for resale. This issue on California, which retails for $5, is available at a 40% discount to dealers. Simply send us a check to cover as many copies as you would like, and we will pay the postage. Our regular issues retail for $3 and are available to dealers at $2 per copy. Write to Mary Lynn White, our circulation manager, if you would like copies for resale. If you like, you can establish an account with us whereby you are shipped a certain number of each issue, along with an invoice, as soon as each issue is published. In California especially, this California issue will probably sell well indefinitely, so you are always free to re-order and we will fill orders as long as we have copies in stock.

There is still time to renew your subscription at the $10 per year rate. Remember that the rate increase to $13 per year will become effective on January 1, 1978. Even if your renewal is not due for a while yet, we will accept it early so that you can take advantage of the lower rate. (The lifetime subscription rate of $150 will go up to $195 on January 1.) As explained in the last issue, you will not be paying twice for any issues if you renew early. Your subscription expiration date will simply be advanced by one year.

As I was going over the records of last year's auction and compiling the list of donors to print in the Europe issue, I kept wondering, "who have I missed?" Sure enough, I missed not one but *two* of the auction's major donors: Prosper Williams (who donated a fine Tsumeb dioptase) and Charles Key (whom I did not realize had been *co*-donor, with Sid Pieters, of a magnificent jeremejevite crystal). I offer my sincere apologies and grateful thanks to both.

THE HISTORICAL RECORD

by Ron Bentley
P.O. Box 366
Windsor, Connecticut 06095

I had planned to follow up last issue's column on label collecting with a column on cleaning and preserving old labels. However, in honor of this special issue on California, I thought it would be interesting to profile some of the major personalities in the history of California mineralogy.

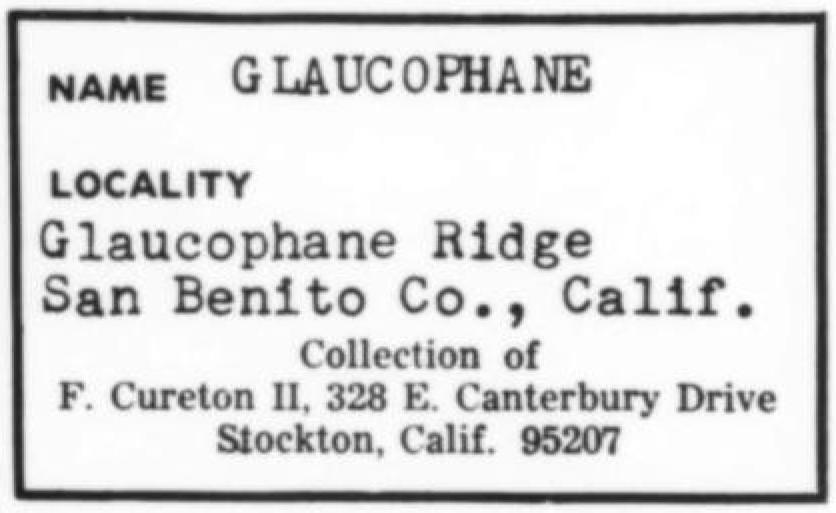
Since 1890, descriptions of 82 new California minerals and more than 300 articles dealing with California mineralogy have been published. Branches of the University of California at Berkeley and Los Angeles were (and still are) major centers of professional research. California's first society, the Mineralogical Society of Southern California, was organized in Pasadena on June 23, 1931. Since then, gem and mineral societies and clubs in California have flourished; today they number over 700 and serve more than 30,000 members. Obviously Californians are active on the amateur as well as the professional level. Although the following profiles deal primarily with some of the state's most famous professional mineralogists, a selection of labels from old (and not so old) dealers, collectors and institutions in California is also included, a random sampling which readers might find interesting.

I have tried to keep the profiles brief. Most of these people have been honored by having a mineral or variety named after them (although some of those minerals have since been discredited); in such cases the mineral or variety name is given in parentheses after their name.

Henry Garber Hanks (hanksite), 1826-1907, was the first state mineralogist of California. He headed the state mining bureau from 1880 to 1886 and his contributions to California mineralogy continued until 1905, including several papers on new California mineral localities.

George F. Becker, 1847-1919, was a pioneer among California geologists. His paper, "Geology of the quicksilver deposits of the Pacific Slope," is a classic and, together with his other studies, defined the mineralogy of California's mercury deposits. His professional career began on the faculty of the University of California at Berkeley, after which he spent 40 years with the U.S. Geological Survey (1879-1919).

George F. Kunz (kunzite, the lilac-pink variety of spodumene), 1856-1932, was a self-taught mineralogist who served for more than half a century as gem expert for Tiffany and Company in New York. In 1883 he joined the USGS and published gem reports for the United States through 1909. His descriptions of gem discoveries in California, particularly in San Diego and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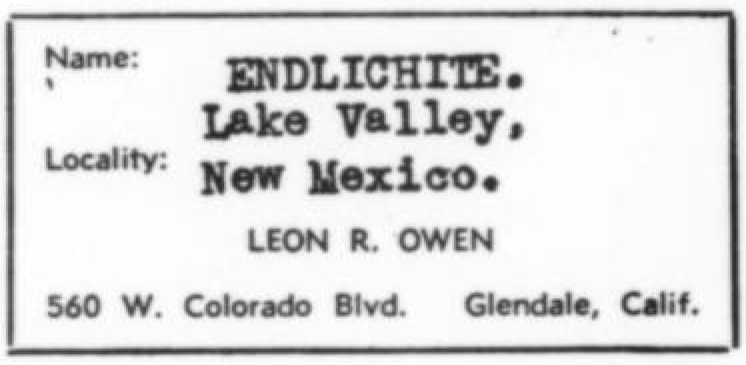
Collection of
F. Cureton II, 328 E. Canterbury Drive
Stockton, Calif. 95207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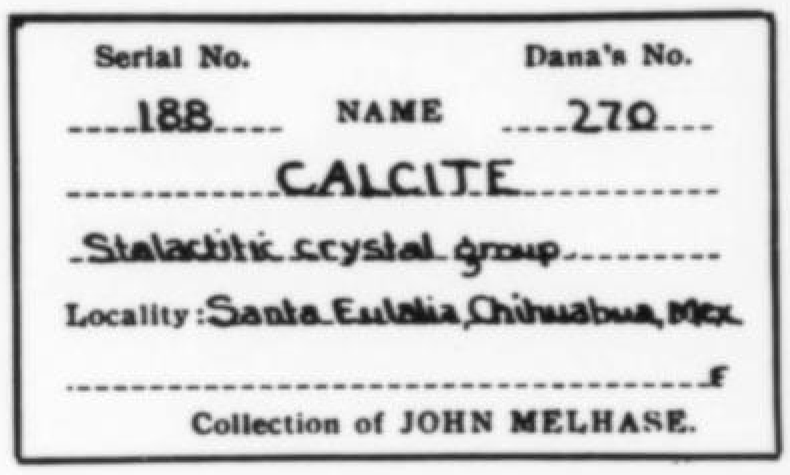
New Mexico.
LEON R. OWEN
560 W. Colorado Blvd. Glendale, Calif.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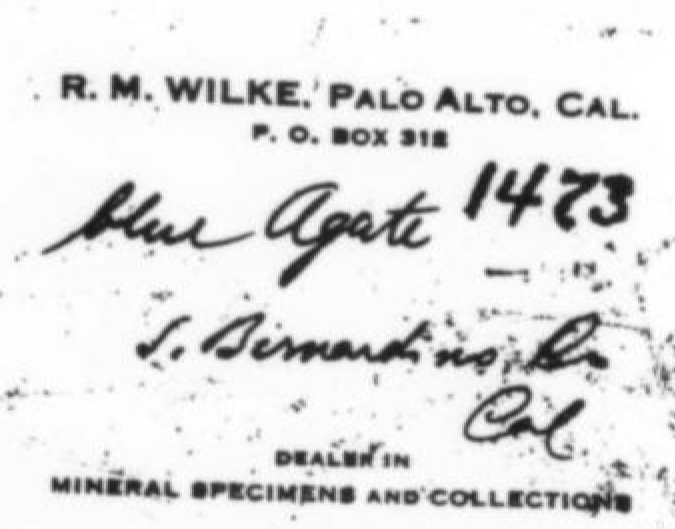
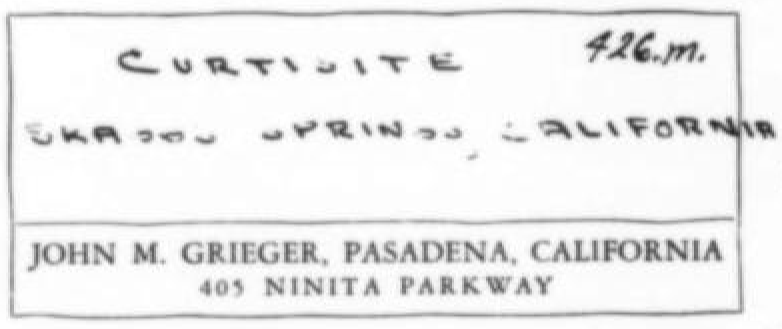
CALCITE
Stalactitic crystal group
Locality: Santa Eulalia, Chihuahua, Mex.
Collection of JOHN MELHASE.


R. M. WILKE, PALO ALTO, CAL.
P. O. BOX 318
Blue Agate 1473
S. Bernardino Co
Cal
DEALER IN
MINERAL SPECIMENS AND COLLECTIONS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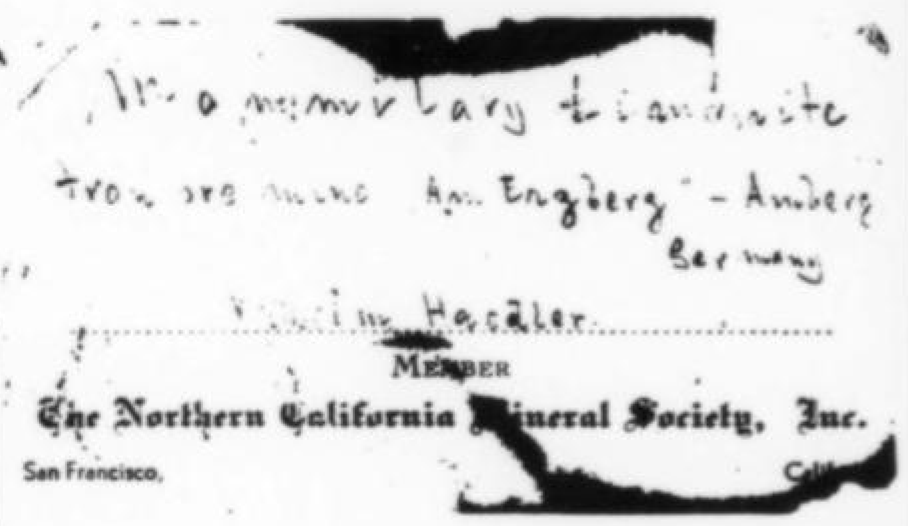
JOHN M. GRIEGER, PASADENA, CALIFORNIA
405 NINITA PARKWAY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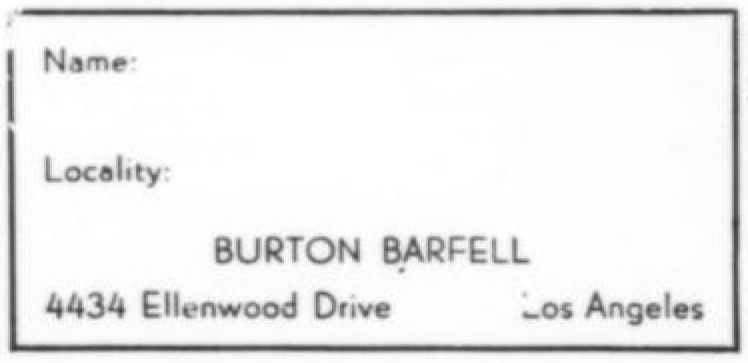
Germany
[illegible] Hasler
MEMBER
The Northern California Mineral Society, Inc.
San Francisco, Calif.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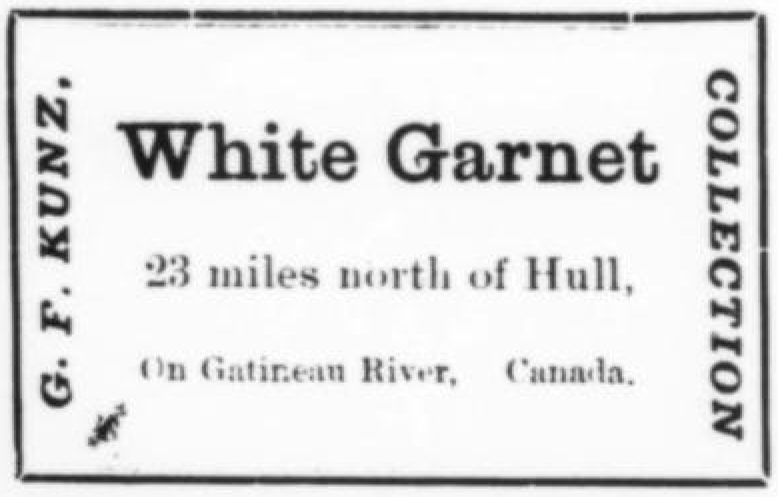
4434 Ellenwood Drive Los Angeles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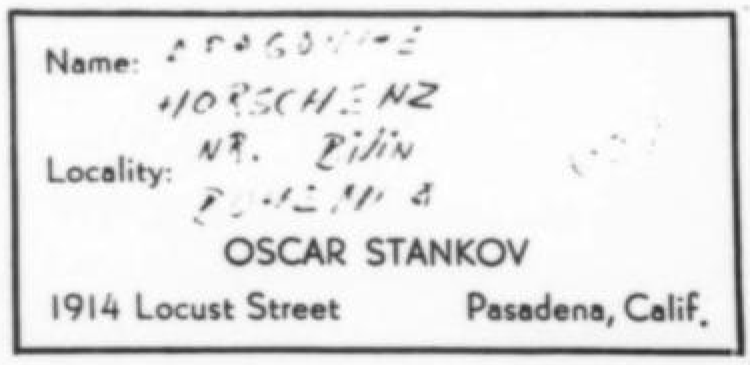
White Garnet
23 miles north of Hull,
On Gatineau River, Canada.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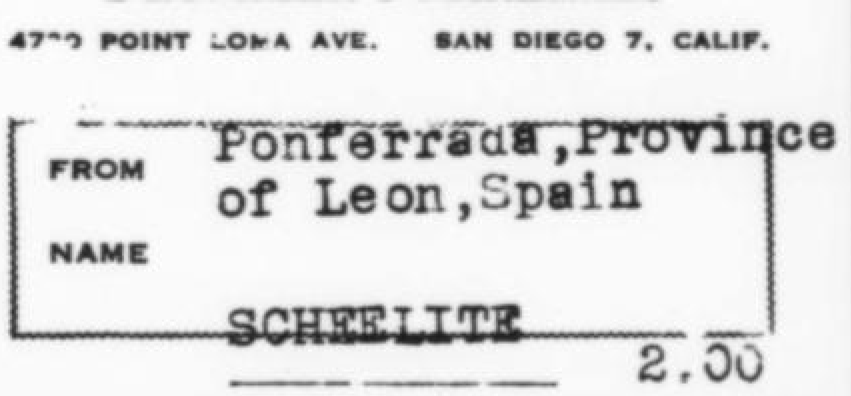
HORSCHENZ
Locality: NR. BILIN
BOHEMIA
OSCAR STANKOV
1914 Locust Street Pasadena, Calif.


PLUMMER'S MINERALS
47 POINT LOMA AVE. SAN DIEGO 7, CALIF.
FROM Ponferrada, Province of Leon, Spain
NAME SCHEELITE
2.00

Riverside Counties, popularized California as a gem state.

Andrew C. Lawson (lawsonite), 1861-1952, pioneered studies of geology and mineralogy in many parts of the state while professor of geology at the University of California, Berkeley. With George Louderback he helped build one of the country's outstanding geology-mineralogy departments. His professional career spans 70 years, during which he described several new California minerals.

Arthur S. Eakle (eakleite, now a synonym for xonotlite), 1862-1931, was professor of mineralogy at the University of California, Berkeley, where he produced research on California mineralogy for 30 years. In 1914 he revived the catalog *Minerals of California* (first published by W. P. Blake in 1866 and later produced by Henry Hanks in 1884). Eakle made the first major study of the now-famous Crestmore quarries, describing a large portion of the 150 or so minerals that occur there. Crestmore species first described by Eakle include vonsenite, foshagite, probertite, riversideite and wilkeite.

Frederick L. Ransome (ransomite), 1865-1935, earned his Ph. D. at the University of California, Berkeley, in 1896. While with the USGS he published many papers on the mineralogy and economic geology of California, and especially on the Mother Lode. He joined the California Institute of Technology in 1927, where he described a new mineral from California which he named lawsonite.

Charles Palache (palacheite, a variety of botryogen), 1869-1954, a native son of California, received his Ph. D. from the University of California, Berkeley, in 1894. He joined the faculty of Harvard University in 1896, where he worked and published until his retirement in 1941. Among Palache's many achievements are his classic paper (*USGS Professional Paper 180*) on the minerals of Franklin and Sterling Hill, New Jersey, and his work with Berman and Frondel on the most recent edition of *Dana's System of Mineralogy*.

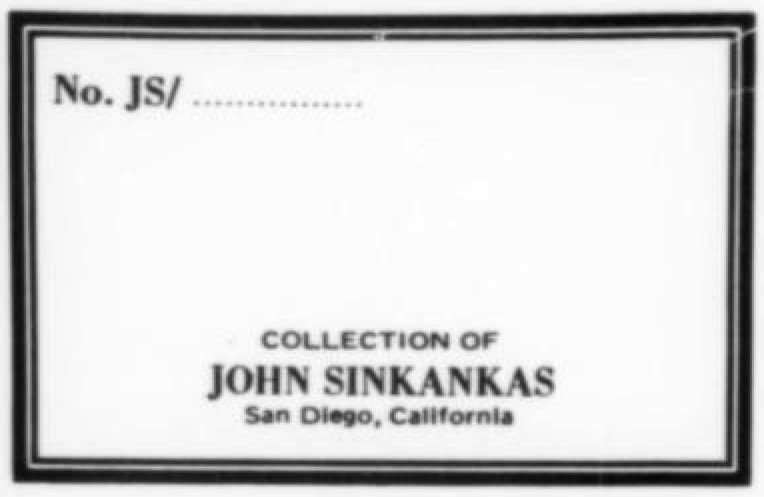
George D. Louderback (louderbackite, now a synonym for roemerite), 1874-1957, also a native Californian, received his Ph. D. from the University of California, Berkeley, in 1899 and returned there to join the faculty in 1906. In 1907 he described the new mineral benitoite, and in 1909 the new mineral joaquinite.

Hoyt S. Gale (galeite), 1876-1952, graduated from Harvard and joined the USGS in 1903. His specialty was the study of western deposits of nitrates, potash and borax. His papers on the saline lake regions defined the history of mineral suites in such areas as Searles Lake (the type locality for galeite).

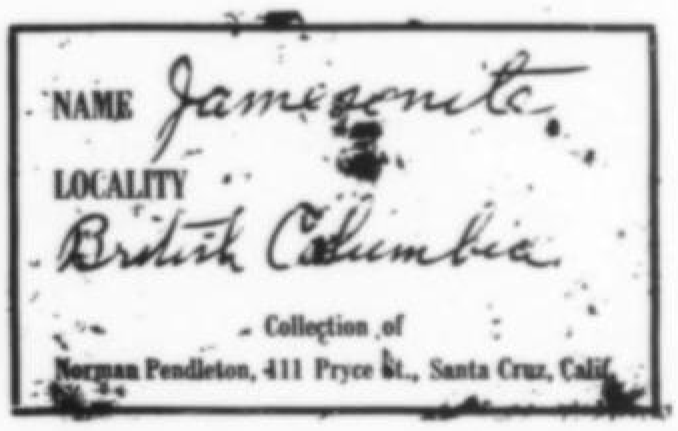
Austin F. Rogers (rogersite, now a synonym for lawsonite), 1877-1957, was a professor of mineralogy at Stanford University for 40 years, and contributed 53 papers on California minerals, including the first descriptions of kempite and sanbornite.

Esper S. Larsen (esperite and larsenite), 1878-1961, received his Ph. D. at the University of California, Berkeley, in 1918. He served on the staff of the Carnegie Institute in Washington, D.C., and the USGS, and finally as professor of petrography at Harvard University. He described several new California minerals including merwinite, searlesite and tilleyite. In addition to his accomplishments in descriptive mineralogy he developed an isotopic age-dating method (for rocks), based on radioactive elements in rare accessory minerals, that is still in use today.

Magnus Vonsen (vonsenite), 1879-1954, like George Kunz, was a self-taught mineralogist best known for his field collecting. His special interest was borate minerals, and it was he who discovered the borate later named in his honor by Eakle. Vonsen


No. JS/ ....

COLLECTION OF
JOHN SINKANKAS
San Diego, California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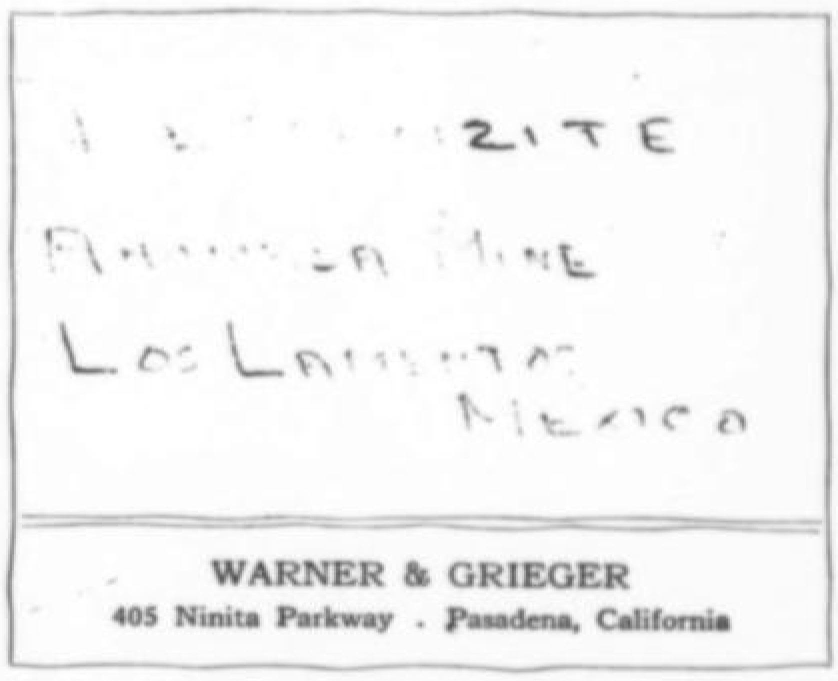
LOCALITY
British Columbia
Collection of
Norman Pendleton, 411 Pryce St., Santa Cruz, Calif.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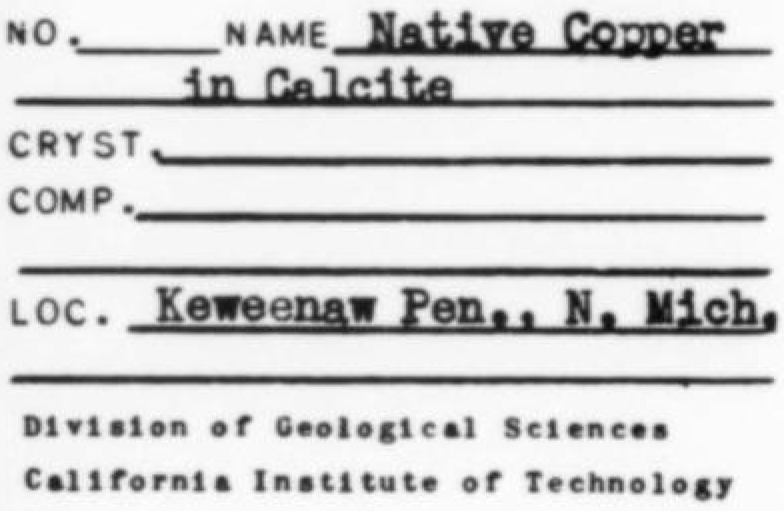
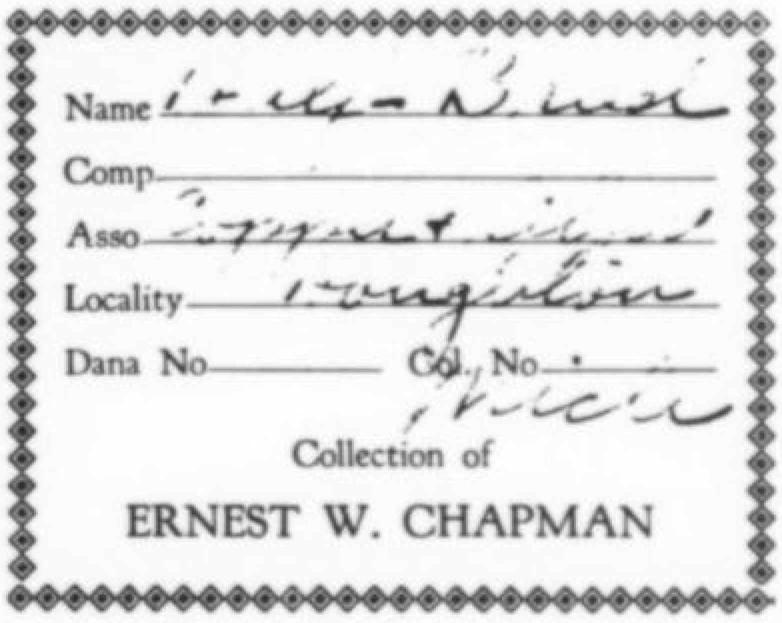
MEXICO

WARNER & GRIEGER
405 Ninita Parkway . Pasadena, California


NO. ______ NAME Native Copper in Calcite
CRYST. ______
COMP. ______
LOC. Keweenaw Pen., N. Mich.

Division of Geological Sciences
California Institute of Technology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Asso [illegible]
Locality [illegible]
Dana No ______ Col. No ______
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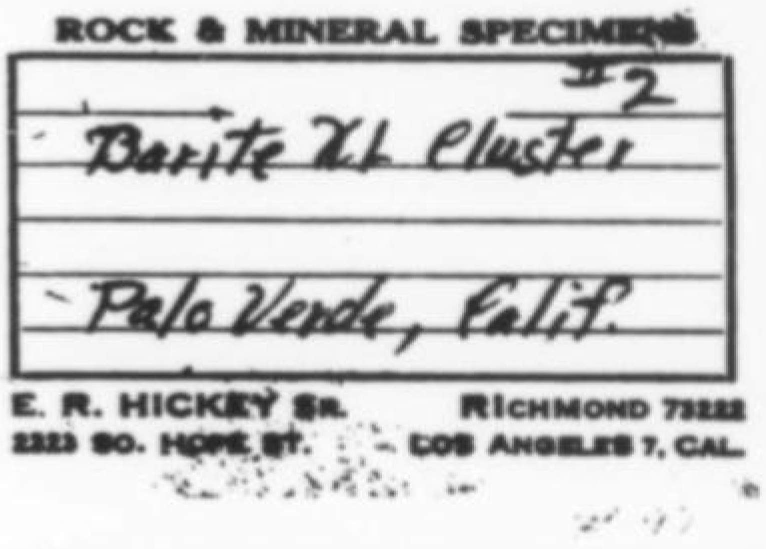
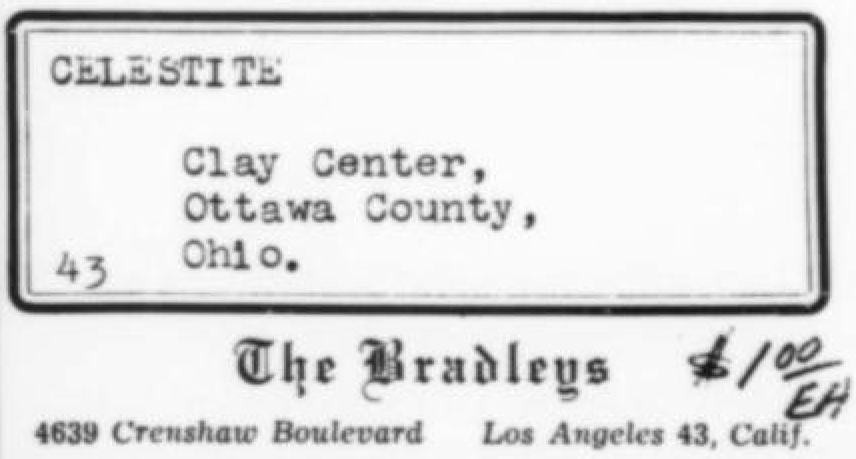
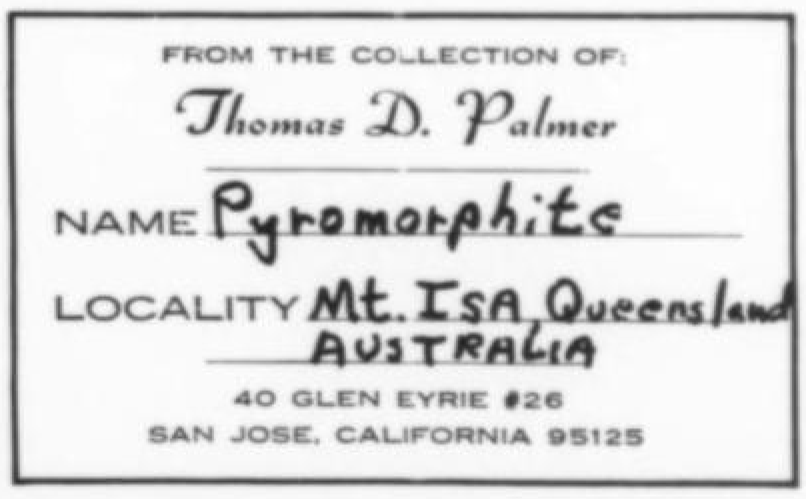
Collection of
ERNEST W. CHAPMAN


ROCK & MINERAL SPECIMENS
#2
Barite Xl Cluster
Palo Verde, Calif.
E. R. HICKEY SR. **RICHMOND 73222**
2323 SO. HOPE ST. — LOS ANGELES 7, CAL.


CELESTITE

Clay Center,
Ottawa County,
Ohio.
43

The Bradleys $1.00 EH
4639 Crenshaw Boulevard Los Angeles 43, Calif.


FROM THE COLLECTION OF:
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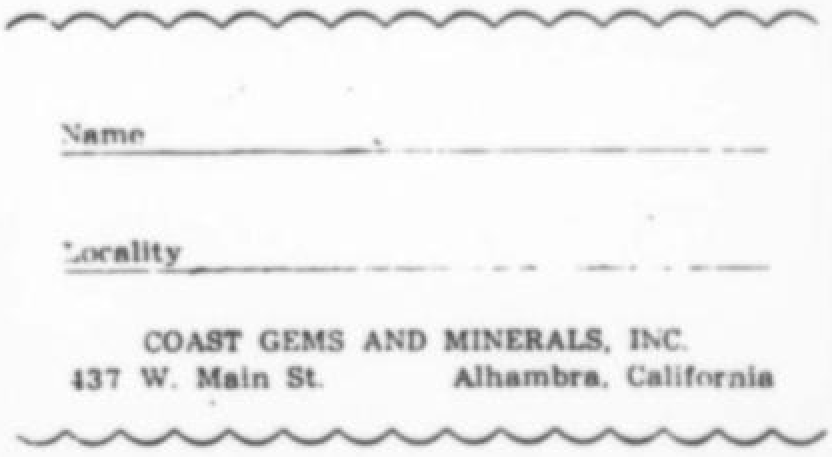
SAN JOSE, CALIFORNIA 95125


Name ______
Locality ______

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437 W. Main St. Alhambra, California

also discovered teepleite at Clear Lake, and reported several new localities for pumpellyite and lawsonite. His fine personal collection was donated to the San Francisco, California, Academy of Sciences.

Waldemar T. Schaller (schallerite), 1882-1967, studied at the University of California, Berkeley, and published more papers on California mineralogy (58) than any other mineralogist to date. He described boothite, salmonsite, sicklerite, stewartite, inyoite, meyerhofferite and kernite. A chemist and mineralogist for the USGS for over 50 years, he received the highest awards of his profession.

Charles Douglas Woodhouse (woodhouseite), 1888-1975, began his career as an attorney with a Master of Jurisprudence degree from the University of California, Berkeley, in 1925. He subsequently studied geology at Stanford University and the Sorbonne in Paris, and became an astute mineral collector as well. He joined the geology faculty of Santa Barbara State College (now the University of California, Santa Barbara), eventually being appointed professor and Dean of Men. He donated his superb collection to his university and also founded the California Federation of Mineral Societies.

Joseph Murdoch (murdochite), 1890-, was educated at Harvard and joined the faculty of the University of California at Los Angeles in 1928. His specialty was ore microscopy and he published several pioneering works on opaque minerals. His published works include 45 papers on California minerals. Murdoch's collaboration with Robert Webb led to editions of *Minerals of California* in 1948, 1956 and 1966.

Henry William Foshag (foshagite), 1894-1956, was appointed curator of minerals at the Smithsonian Institution in 1919, and was awarded a Ph. D. in 1923 from the University of California at Berkeley. Foshag published more than 30 papers on California mineralogy including the first descriptions of plazolite, schairerite, krausite and burkeite.

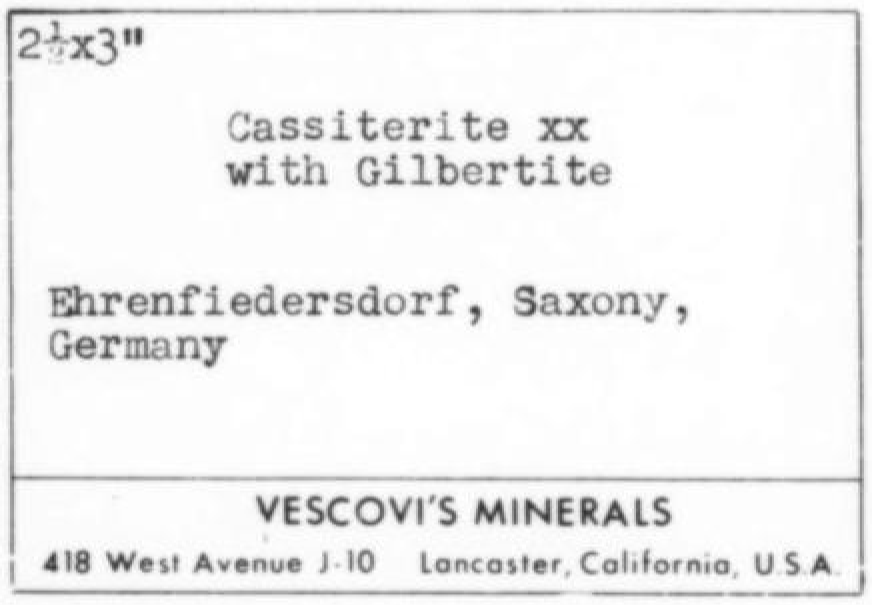
Adolf Pabst (pabstite), 1899-, received his Ph. D. from the University of California, Berkeley, in 1928. His list of publications, mostly on California mineralogy, numbers over 20 and is still increasing (see his article on the new California mineral jonesite in this issue). He authored *Minerals of California* (1938 edition) and in 1965 was awarded the Roebling Medal for distinguished contributions to mineralogy and crystallography.

Robert W. Webb, 1909-, received his Ph. D. from the California Institute of Technology in 1937. His publications include over 65 papers, many on the geology and mineralogy of California. Webb served on the staff of the University of California, Santa Barbara, for over 40 years, excelling as an administrator as well as a mineralogist. He collaborated with Murdoch on three editions of *Minerals of California.*

Other mineralogists among the many deserving mention include **George Switzer** (switzerite), a former curator of minerals at the Smithsonian, **George Tunell** (tunellite), still active at the University of California at Santa Barbara, and **William Nisson** (nissonite) of the California Bureau of Mines Museum.

A discussion of the collectors and dealers who have contributed to the study of California mineralogy would be long indeed, and might make an interesting future column.

I would like to express my deep appreciation to the following people for their help in compiling the information and labels in this column: Dona and Wayne Leicht, Paul Desautels, Jesse Hardman, Juanita Curtis, John White and William McCarty.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Cassiterite xx
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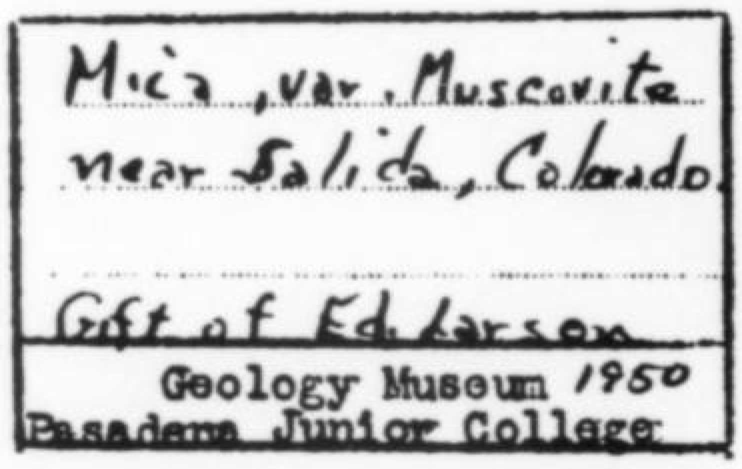
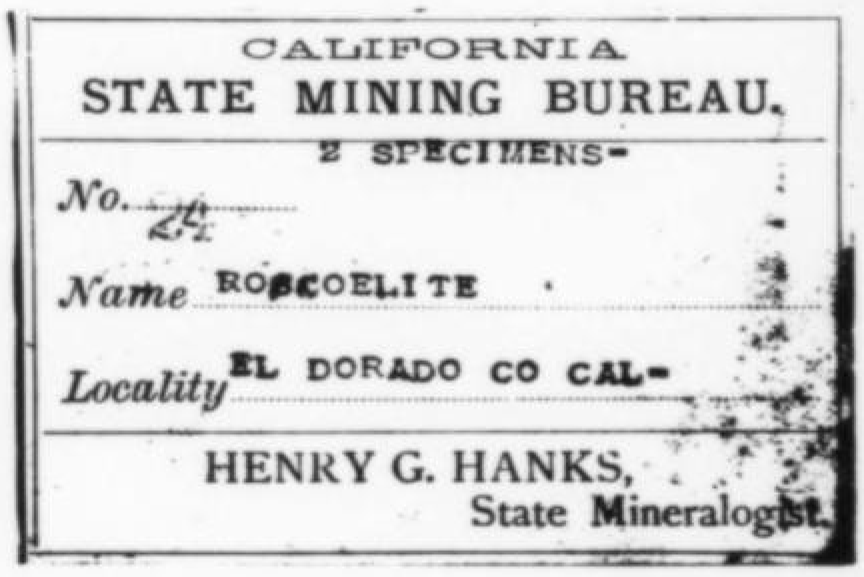

Mica, var. Muscovite
near Salida, Colorado

Gift of Ed. Larson

Geology Museum 1950
Pasadena Junior College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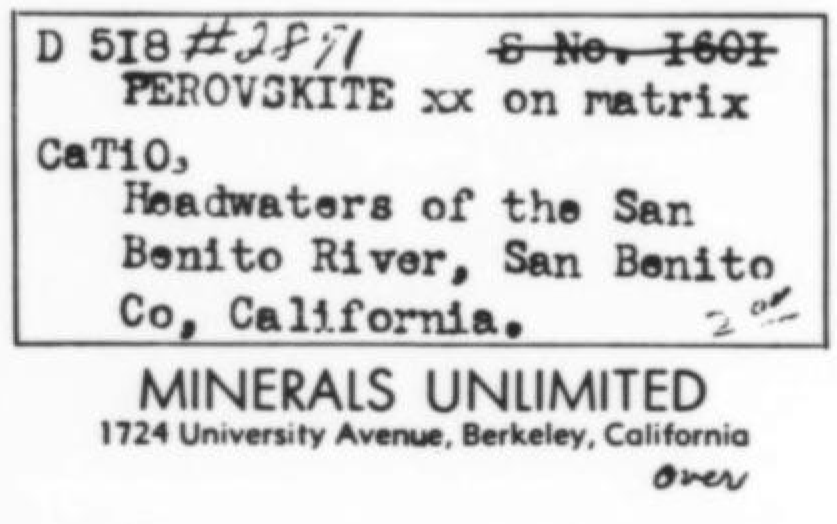
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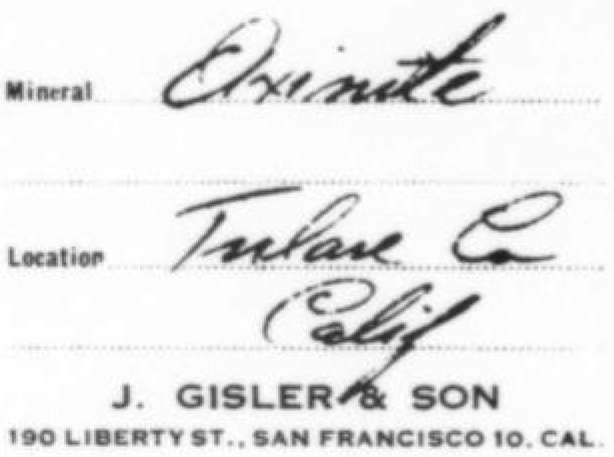
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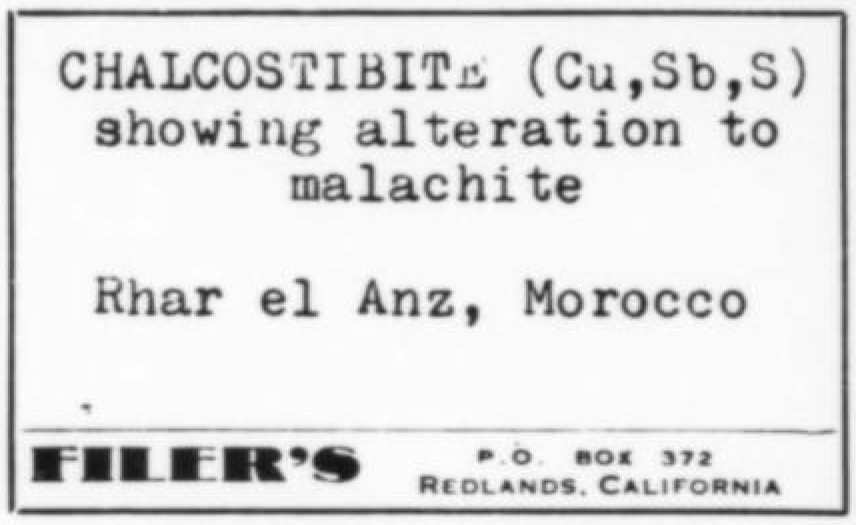
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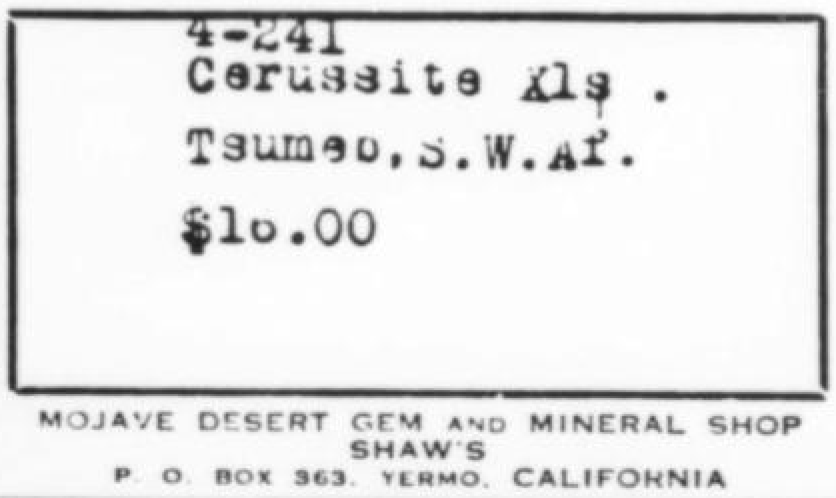
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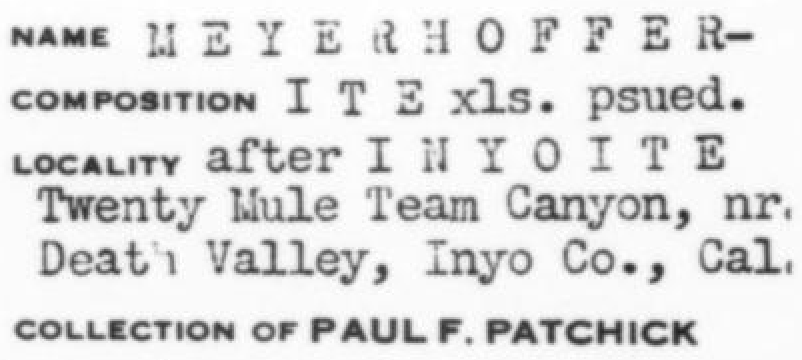
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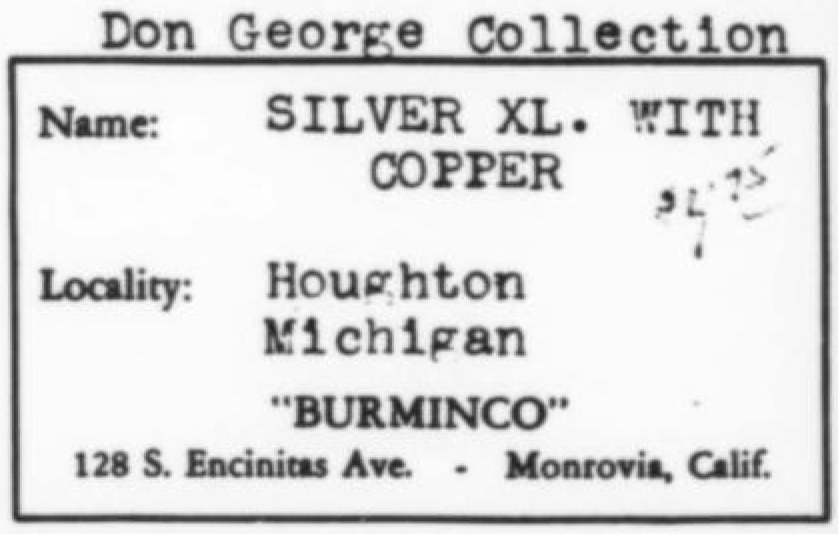
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Microminerals

by Violet Anderson

Neal Yedlin should be writing this column. There is no one quite like him. He has his own particular style of intimacy, dignity, and relaxed humor all in one, and we're going to keep right on wishing to see him back on the job. I cannot do what Neal does. I can only dig for, stumble over, or fall heir to a few facts that may be of some use to micromounters.

This issue of the magazine being on California, it seems appropriate to find out something of what that state has to offer in microminerals. A Torontonian, some 3000 miles from Searles Lake or the headwaters of the San Benito River, is not in the best position for such a task, but with the help of Hatfield Goudey, Fred DeVito, and Sharon Cisneros, all of whom sent me written material or minerals or both, there just might be a few paragraphs following. I'll not try to cover all the microminerals to be found in such a large state as California (which must run into the hundreds), but rather will do a here-and-there job based on the California microminerals that I — away off here on the edge of the Precambrian Shield — have found available on the mineral market or through exchange.

The complexity of California geology is staggering, and the topography, as observed in aerial photographs of such geological provinces as the Sierra Nevada and the Great Basin (with its dry lakes and Death Valley) shows a ruggedness and bleakness which for the field-collector must be intimidating. And yet it is from Death Valley and the famous Searles Lake, in the southern part of the Great Basin stretching from the 39th parallel to the Mohave Desert, that many of my own California microminerals have come.

Most of the lakes are playas, dry lakes becoming marshes only in a rainy season, followed by the evaporation of their moisture and deposition of salts. The minerals produced (evaporites) are usually water-soluble as well as showing a tendency, great or little, to alter or crumble if they lose what water they possess. Searles Lake has accumulated hundreds of feet of such deposits over a period of thousands of years. Mineral species include many chlorides, carbonates, and sulfates of sodium, calcium, potassium, and magnesium, and a few borates.

As a protection for certain minerals such as these against atmospheric change, Allan Mitchell of *Microminerals International* uses a small circular cell (like a miniature hat-box, if you can remember such objects) and although I doubt if the minerals could be photographed through the covering and under the heat of the lamp, they can be mounted, cell and all, and observed with pleasure, since many of them have attractively sharp faces. The crystals, devoid of matrix, can be rolled about and the different forms studied. With perhaps three or more crystals of the same mineral in the cell, it is something of a game, since rolling one will roll the others.

The minerals that I have from Searles Lake (San Bernardino Co.) mounted in cells are not borates but sulfates (hanksite, sulphohalite, and schairerite) and carbonates (gaylussite and pirssonite). Micromounters should have them all. The hanksite is particularly attractive, showing little hexagonal barrels closing in at top and bottom with rings of bipyramidal faces which, being of differing slopes, interrupt each other until the terminations are reached, perhaps in pinacoid faces. Gaylussite is equally interesting, a monoclinic mineral with a variety of forms, although gaylussite, unlike the other four, is not a mineral first discovered in California.

Tychite and northupite, however, are. They are carbonates, also from Searles Lake, similar to each other both in composition and habit. They are tiny colorless or whitish octahedrons, again without matrix. Perhaps they too should be protected against the air, but they would look pleasing mounted on fine drawn-glass pedestals, if one could master the art of glass-drawing. Bob Gait of the Royal Ontario Museum is a devotee of such pedestals for tiny crystals and, with Cynthia Peat to hold one end of a glass rod for him, will heat the glass over a blow-torch until, at the right moment, each must dash across the room in opposite directions at a speed judged to keep the hot glass from cooling and hardening before it is fine enough. After that, hopefully — many pedestals needle-thin.

Colemanite (white to yellow) from the Jenifer mine, Boron, California. Size: 1 cm high. Specimen and photo: Werner Lieber.

Death Valley, to the east of Searles Lake, in Inyo County, has very similar climatic conditions: hot and arid. The lowest point on the Continent is in Death Valley, 282 feet below sea level, and the valley is believed to be still sinking. From the Russell mine in this area I have celestine crystals with colemanite crystals on a colemanite matrix; from the Hardscramble mine, gowerite, fine acicular clear crystals, associated with "cotton-tuft" ulexite, and with small plates of clear nobleite: all three are borates. Inyoite and meyerhofferite, borates from Corkscrew Canyon, are found together. They are identical as to chemical formula except that inyoite has more water; both are colorless to white. Inyoite is short monoclinic prismatic; meyerhofferite is elongated and triclinic. Meyerhofferite is an alteration product

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Ed. Note: Neal Yedlin passed away on October 8, just as this issue was going to press. A biography of Neal will appear in a future issue.

of inyoite. Sometimes, however, the inyoite morphology is retained, in which case one has a pseudomorph of meyerhofferite after inyoite. There are times when it is difficult to know what one has.

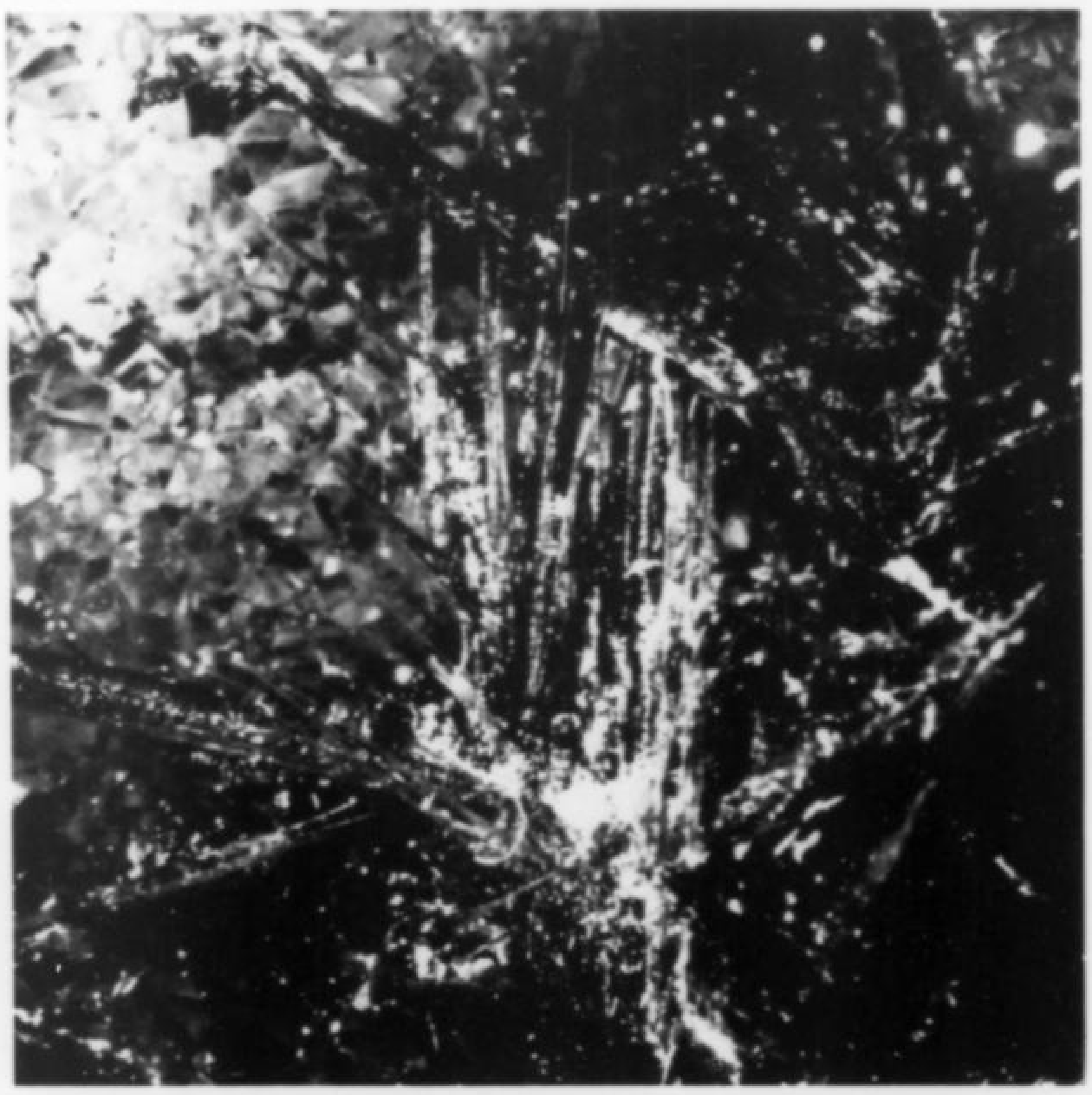
Gowerite, nobleite, inyoite and meyerhofferite were all discovered first in California.

From Boron, in Kern County, come still more borates: hydroboracite (tiny clear blades), tincalconite (a powdery mineral usually only found coating something else), and colemanite (the king of the borates), which occurs in neatly formed monoclinic crystals. The last two were first found in California. Not so the wispy sulfate, halotrichite, which grows such long silky fibers that it was only after much searching at Tucson last year that I found a specimen suitable for photomicrography. Its locality: the Golden Queen mine, Mohave, Kern County.

San Bernardino County is the largest county in California. It includes not only the playas but nearby mountains. In the far east, in the Clark Mountains, is the Mohawk mine which contains azurite, cuprian adamite, and also the triclinic chalcophanite (an oxide) whose crystals on matrix resemble small dark halfmoons. On top of the chalcophanite are black octahedrons of hetaerolite (another oxide). These last two seem to have been found only recently in California. At Lead Mountain, near Barstow, Herb and Geneva Corbett have collected hemimorphite and barite, and as usual have been generous with their finds to their many friends. From the Blue Bell mine at Baker (see the article elsewhere in this issue) come dioptase (in needle form) and caledonite, as well as chrysocolla with aragonite and embolite (the last a silver chloro-bromide). Most of these are a colorful change from the clear to white minerals of the playas, although none of them was found first in California. Neither was miargyrite, which occurs at the Kelly-Rand mine, Randsburg, a silver antimony sulfide, monoclinic, black with glints of red, and the crystals striated. Hatfield Goudey writes: "The Kelly mine crystals are probably the best in the world...the number of forms seems infinite."

Zinc-lead-copper districts in this part of the state include not only those in San Bernardino County but also districts at Cerro Gordo and Darwin in Inyo County. Hatfield Goudey has sent me an unusual specimen from Darwin which includes three lead minerals forming wheels within wheels, a "cross sectional demonstration of gradation from galena through anglesite (dark gray) to cerussite crystals." In the past he has also had brochantite, caledonite, and linarite from Darwin. From Cerro Gordo I have only hemimorphite, although this locality has also produced colorful species in the past, and may be doing so still.

Before hopping the Sierra Nevada Range, one should mention the cristobalite with fayalite from Cosa Hot Springs in Inyo County and the trigonal phosphate, woodhouseite, with its quite simple pseudo-cubic crystals, near-white, and associated with quartz, from the White Mountains in Mono County (see the article on the Champion mine in this issue), one of the many minerals found first in California.



Halotrichite *(left)* (white), from the Golden Queen mine, Mohave County, California. Specimen height: 1.5 cm. Specimen and photo: Werner Lieber.

Montroydite *(above)* (red), from the Socrates mine, Pine Flat, Sonoma County, California. Needle length: 1 cm. Specimen and photo: Werner Lieber.

The Sierra Nevadas...well, undoubtedly there's gold in them thar hills yet, and certainly there are barium minerals, since the type locality for many of these is Big Creek, Fresno County, but for the micromounter, minerals from the Coastal Ranges seem to be the more readily available.

So the Coastal Ranges it is. San Benito County, in the Diablo Range, provides beautiful neptunite, benitoite, and joaquinite, the last two of which were first discovered here (see the article on this locality elsewhere in this issue). Neptunite and benitoite may have large crystals, of course, but they also occur as micros, and constitute the *sine qua non* of any micro collection. Large crystals of benitoite tend to be showy blue trigonal bipyramids, small crystals are lovely pale blue hexagonal plates with large pinacoid faces. Neptunite shows rich red inner fire. One of my own neptunite specimens has fibrous greenish crossite (an amphibole) wandering around it. Also found near here are attractive yellow crystals of andradite on serpentine, often along with deep black cubic crystals of magnetite. Black melanite garnet crystals occur with perovskite crystals in the same area. The perovskite may be black or a nice amber, cleanly formed. The artinite from here (see the article in this issue) has beautiful satiny white crystals against green serpentine, or is associated with little balls of white dypingite — a pleasing contrast in shapes. Cinnabar, from the New Idria mine, has small bright red tabular crystals.

From Sonoma County, further north along the coast, the cinnabar crystals show long trigonal prisms. Light brownish red almandine garnet on glassy green omphacite (a pyroxene) occurs near Petaluma. And glossy black hematite plates sprinkled among yellow siderite crystals are found near Cloverdale. Montroydite, a mercury oxide, a mineral with the soul of an artist, performs as bent and twisted crystals at the Socrates mine.

Further north still, in Mendocino County, Deer, Howie and Zussman have left their mark in silicates named after them and first found in the Laytonville district. The first two, deerite and howieite, are similar: radiating brownish-black prismatic crystals, rather tightly packed but with a lively luster (aegerine comes with the howieite on my specimen, and one has to be greatly persistent to untangle the two, or even to believe one has done it). Zussmanite I do not have; it is said to occur in pale green tabular crystals. Riebeckite, also from near Laytonville, is again in long dark prismatic crystals but they are set off by the sparkle of quartz. From the Russian River comes jadeite, more exciting because (at least in my specimen) the light green acicular crystals are terminated, which is rare. Finally, from Red Mountain, comes the new mineral, vuagnatite (once again, see the article in this issue!) which is pale greenish, glassy, and botryoidal.

Trinity County is too far north for the Coast Ranges and is into the Klamath Mountains geological province, but I mention it here for its inesite, the calcium manganese silicate which forms pink triclinic crystals found at the Hale Creek mine, and which most micromounters like.

Some distance south again from these mountains and past Mendocino County is Lake County, the county of Borax and Sulfur Bank, famous collecting areas. I have two specimens from this county: a rather pale sulfur with the crystals nicely isolated for photography; and from Siegler Canyon tridymite with pargasite (the latter differing from hornblende only in its having no required Fe). It shows clean brown prisms with sharp termination; the clear little hexagonal plates of tridymite are very pretty. There are also some small gatherings of pale brown biotite mica on the specimen.

The lawsonite I have comes from Marin County near San Francisco. This is another first for California. The crystals are white to pale pink, orthorhomic, and look like somewhat off-beat or skewed bipyramids.

Contra Costa County, with its Mt. Diablo mine, is so close to San Francisco that some minerals there have become endangered species, if not locally extinct. I have metacinnabar from this area, one of California's "new" minerals, which was the black sulfide used at the Mt. Diablo mine for mercury ore. As a collector's item it is more humpy and bumpy than mercurial. Its crystals are tetrahedral in habit, but tend to crowd in on each other, making for some difficulty in perceiving forms.

On Mt. Hamilton in Santa Clara County just southeast of San Francisco, melanophlogite was discovered in 1971 or '72, the third or fourth occurrence in the world. The formula seems not yet to be definitely settled, being given in *The Glossary* as SiO_2 containing C and S. The rare crystals resemble cubes and are clear as ice. They may be cubic or tetragonal.

For zeolites, one looks perhaps first and foremost to Tick Canyon in Los Angeles County where are found long acicular brilliantly clear natrolite crystals and analcime crystals. From near Agoura in that county come ferrierite and clinoptilolite.

Not far from Los Angeles, at Pt. Rincon in Ventura County, may be found the gamma-sulfur, rosickyite. The crystals are monoclinic — very small, pale yellow, and platy.

The final geological province I'd like to mention is the Peninsular Range in the far south of the state. For the nonce, that means Riverside County and Crestmore quarries. From Crestmore I have in my collection: minium (such as it is), idocrase (an interesting shallow bipyramid), and graphite. Period! And yet the Crestmore quarries are famous, said to have produced the third largest number of species in the world — after Langban, Sweden, and Franklin, N.J.. Fred DeVito has sent me two excellent papers on Crestmore, one written by Fred and two associates, one by Fred alone. Of the 140 minerals mentioned and briefly described, we can by-pass all the best known and the minerals which appear only as coatings or crusts. That leaves about 35 unusual minerals which it is possible to find in crystal form, but which are just not available for purchase as far as I know. In fact, few of even the better known species seemingly are reaching us in the East. Perhaps, like the minerals of Mont St. Hilaire in Quebec, the supply is limited. I should like to be wrong.

Letters on matters micromineral will be gratefully received.

Violet Anderson
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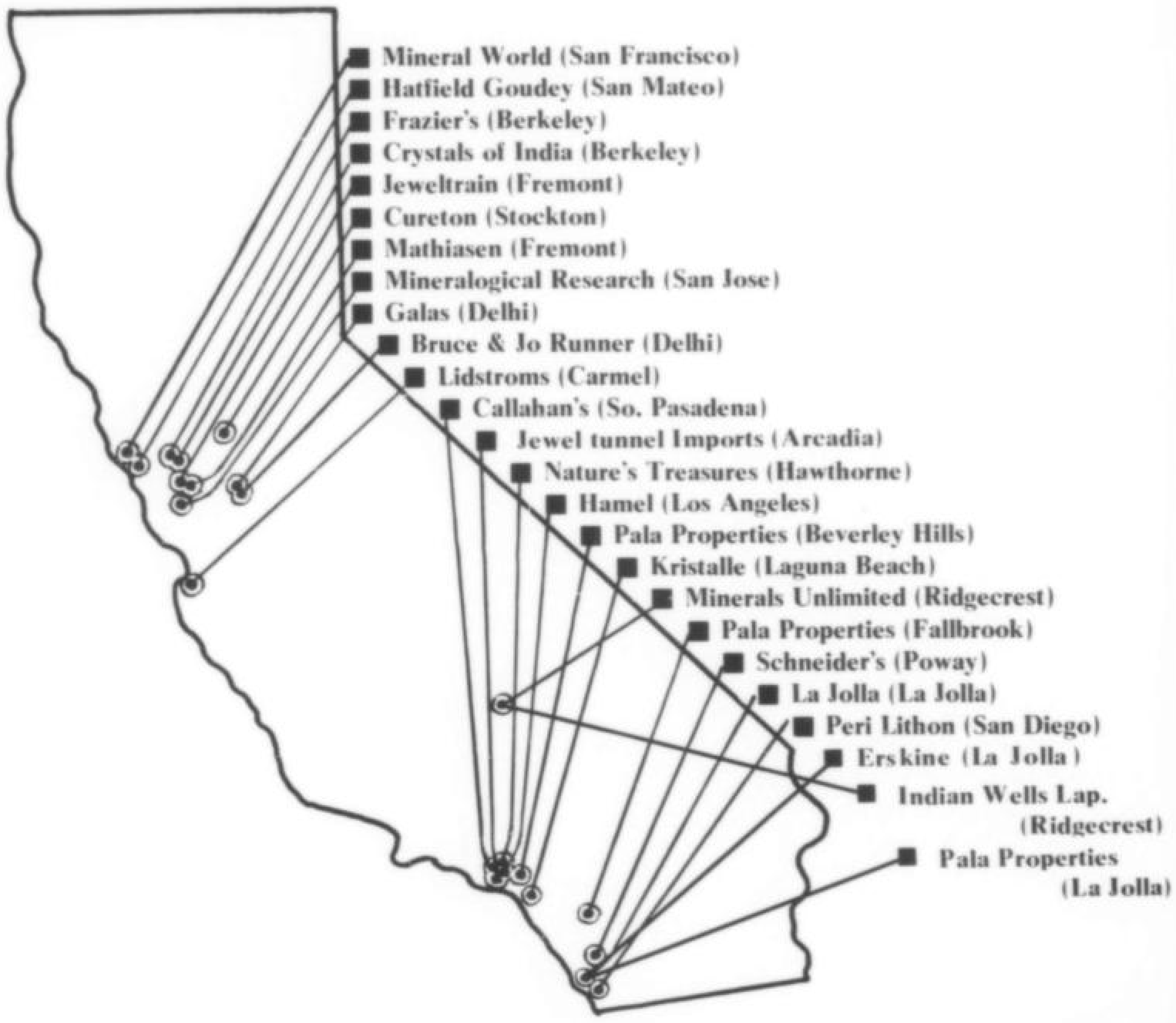

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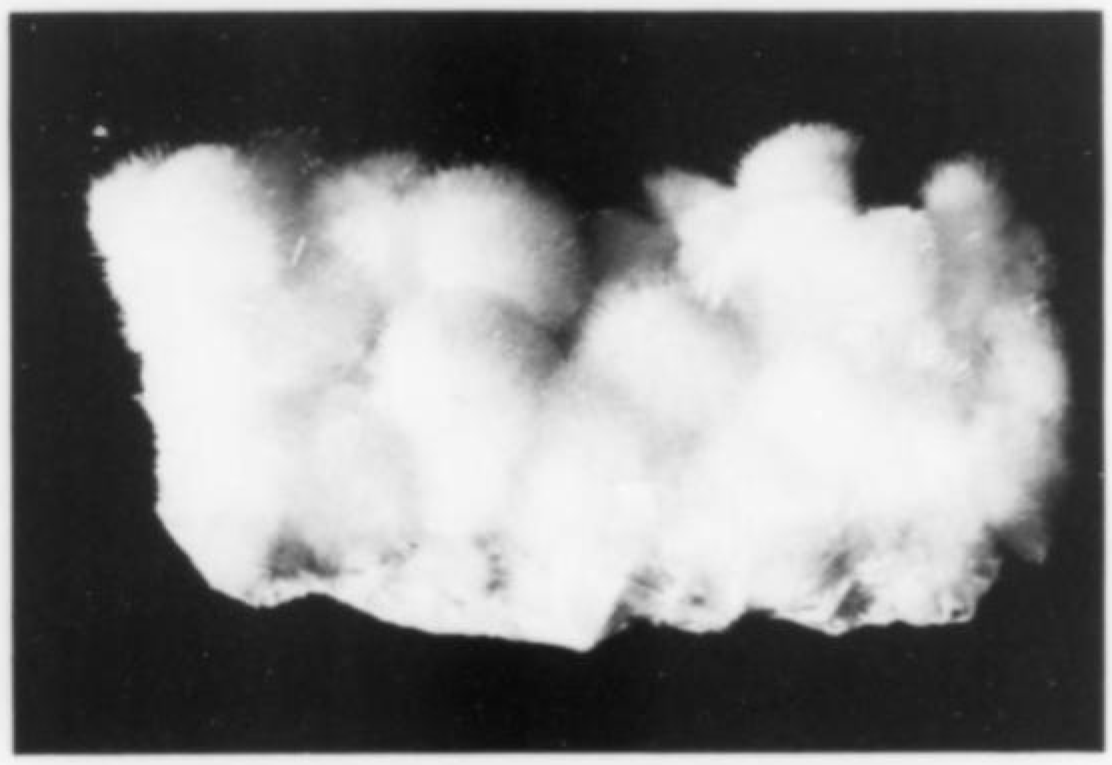

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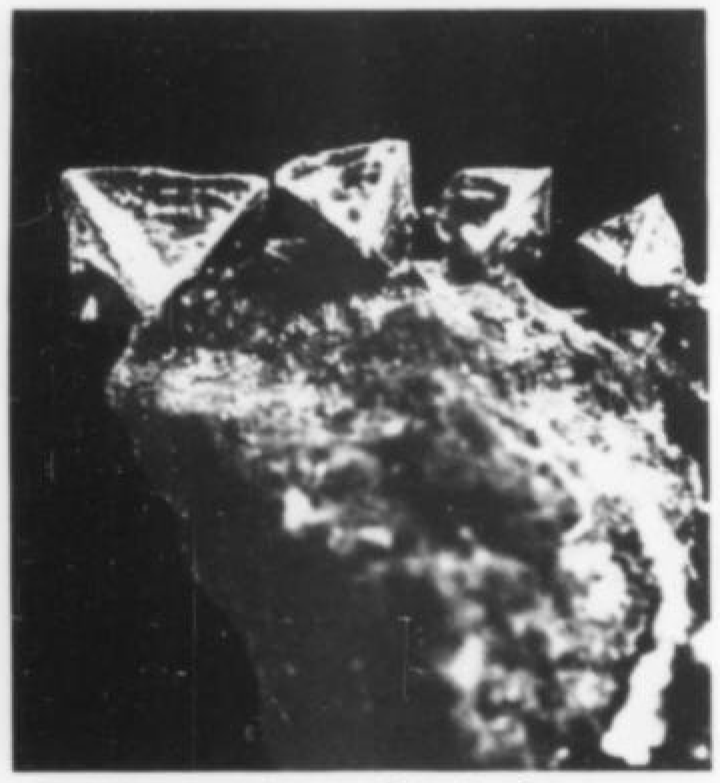


Gold crystals to $\frac{3}{16}$ inch on matrix, from the Colorado Quartz mine, Mariposa County, California. John Barlow collection; photo by Wendell Wilson.

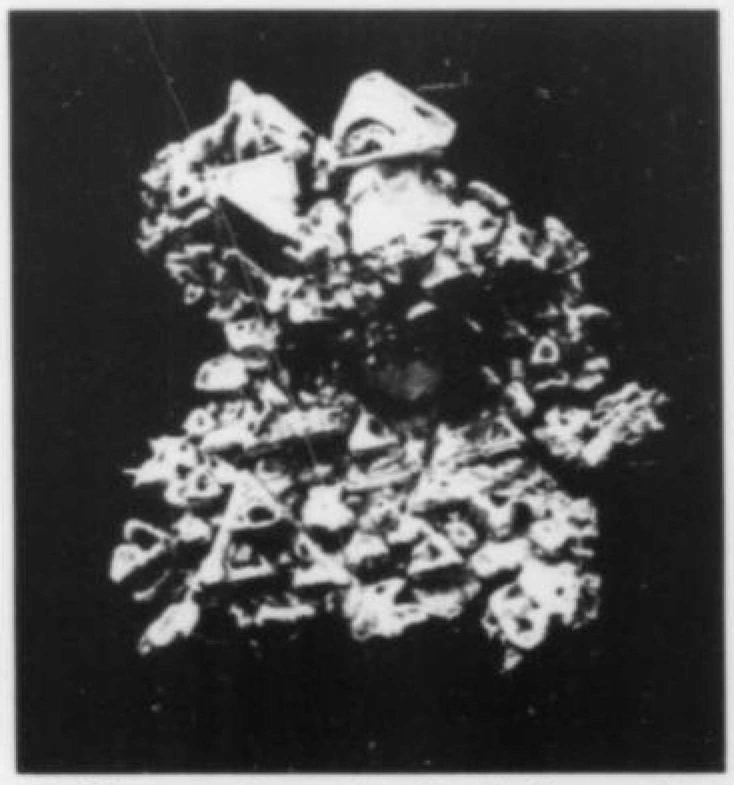
When thinking of California, one envisions warm and beautiful coastlines. But when thinking of the *minerals* of California, **gold** quickly comes to mind! Over the years California has been one of the world's most prolific producers of fine crystallized gold. From her many mines have come some of the finest golds ever to grace the many major museums throughout the world. Today California is still continuing its illustrious history. In this article we are not speaking of gold specimens mined 20, 30, or 100 years ago, but rather newly mined specimens which are the equal of anything ever found in the past.

When production began at the Colorado Quartz mine in Mariposa County, California, it was worked strictly for ore and not for specimens. The rich gold vein was discovered as a surface outcrop, and a deep shaft lined with steel-reinforced concrete was sunk at the discovery point. Unfortunately the discovery hole produced an insignificant amount of specimen gold.

Eventually another shaft was sunk about 150 feet from the discovery shaft. This new shaft eventually reached a depth and a diameter of about 40 feet, where a heavy flow of groundwater required the installation of a pump. Drifts were driven horizontally and encountered more gold ore, along with some promising signs of specimens. A large pocket of quartz crystals was encountered in which the crystals were waterclear throughout, except for milky bases. Minute crystals of gold were found along fractures in the quartz crystals, causing some excitement among the miners...perhaps specimens of gold growing out of quartz crystals would soon be found! However, after completely removing about 200 pounds of hand-size and larger quartz crystals and groups from the pocket, no spectacular gold specimens had been found.

The drift was driven horizontally for another 20 feet. In April of 1976 the miners entered the mine as usual. They climbed down a 10-foot section of ladder to a platform, then down another section of ladder to another platform, and so on, until reaching the bottom of the shaft. After only a short period of work at the tunnel face they broke into a collector's dream: a small pocket of beautifully crystallized gold specimens! The pocket was eagerly but carefully removed, and the tunnel was advanced another 10 feet without finding anything more. Their discovery had been a small, isolated pocket.

Some of the specimens were purchased by a dealer in San Francisco and sent to Europe. The others made their way to the California Federation Show in San Francisco in July of 1976. At this show the major pieces of the pocket were sold to collectors.

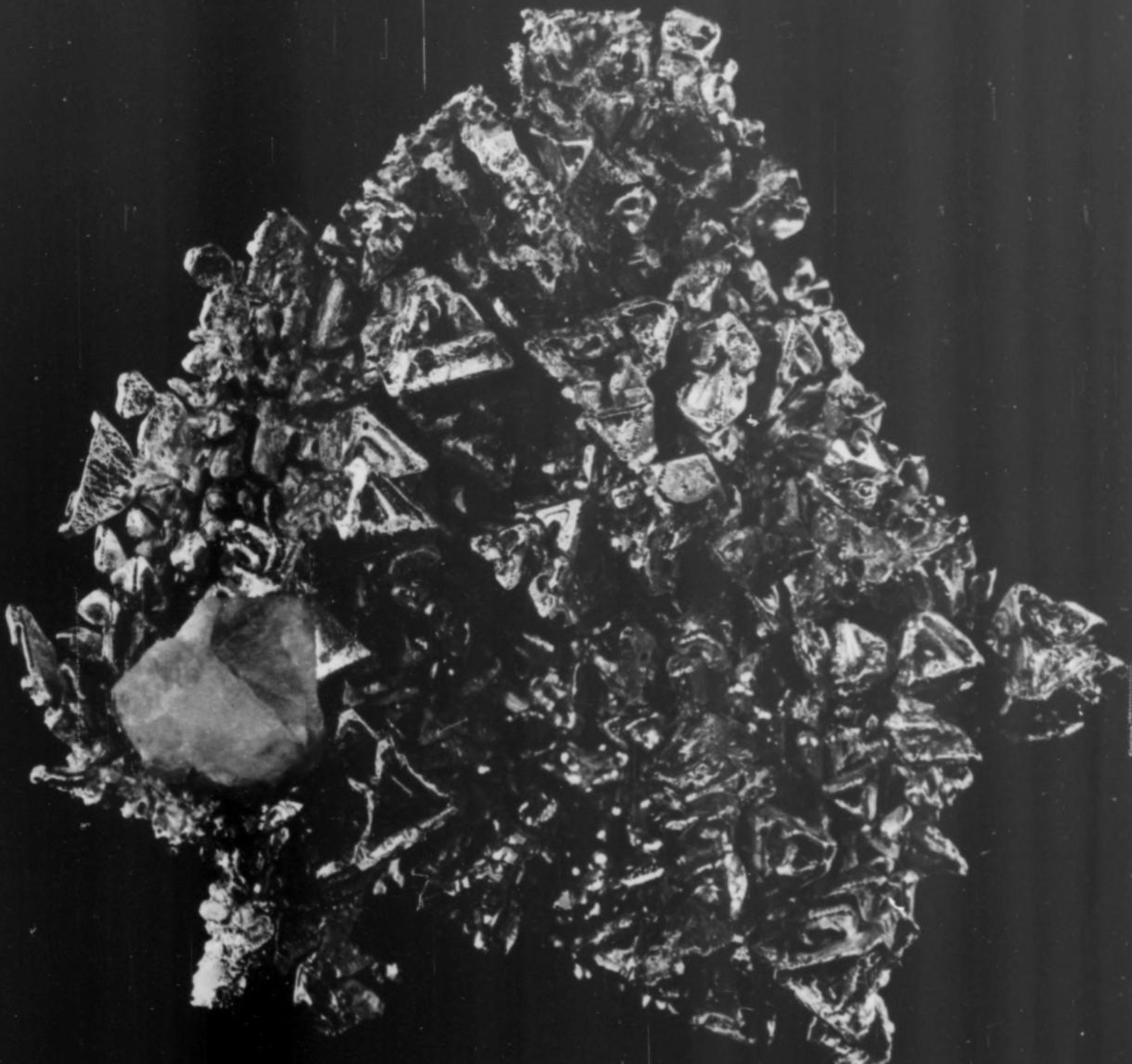


Gold crystals to $\frac{1}{4}$ inch from the Colorado Quartz mine, Mariposa County, California. Siber and Siber specimen; photo by Eric Offermann.

I obtained one of these specimens at the show myself. After working at the show most of the day I was feeling rather disappointed at not yet having found anything I really liked (and that was for sale). Then a friend came up and asked me if I would like to look at something; I said sure. We left the booth and kept walking until we were out of the building and in the parking lot. I asked where his car was and he replied, "what car?" Then he handed me the gold miniature pictured here on the facing page. The specimen, as you can see, has exceptional color, sharpness and luster. It measures slightly under 2 x 2 inches, and bears crystals $\frac{1}{8}$ to $\frac{1}{4}$ inch in size. This specimen, for overall quality, is the finest found in the pocket, and is easily one of the finest miniature gold specimens ever found in California.

Another specimen was acquired by Bryant Harris, a mineral collector in Fallbrook, California. His specimen is the largest matrix piece removed from the pocket. The matrix measures $1\frac{1}{2}$ x $1\frac{1}{2}$ x 3 inches; standing straight up on this matrix are two arborescent groups of gold crystals. Each group is $1\frac{1}{16}$ inches tall and is composed of $\frac{1}{8}$ to $\frac{3}{16}$-inch gold crystals, all very bright, sharp and yellow. The finest thumbnail of the pocket is 1 x $\frac{1}{2}$ inch in size, and is composed of $\frac{1}{16}$ to $\frac{1}{8}$-inch crystals in a twisted, arborescent group (collection of the author). The second finest miniature and several thumbnails were purchased by an Eastern collector. The miniature is 1 x $1\frac{1}{2}$ inches in size, with a finely arborescent group of gold crystals and a $\frac{1}{4}$ x $\frac{5}{16}$-inch quartz crystal on quartz matrix. On the back of the specimen is a razor-sharp, mirror-bright octahedron of gold $\frac{1}{4}$ inch in size.

The future of the Colorado Quartz mine is uncertain, and appears hopelessly entangled in legal difficulties. It is doubtful that more specimens will be coming from this mine, at least in the near future. But this locality has proven that the great gold-producing days of California are far from over!

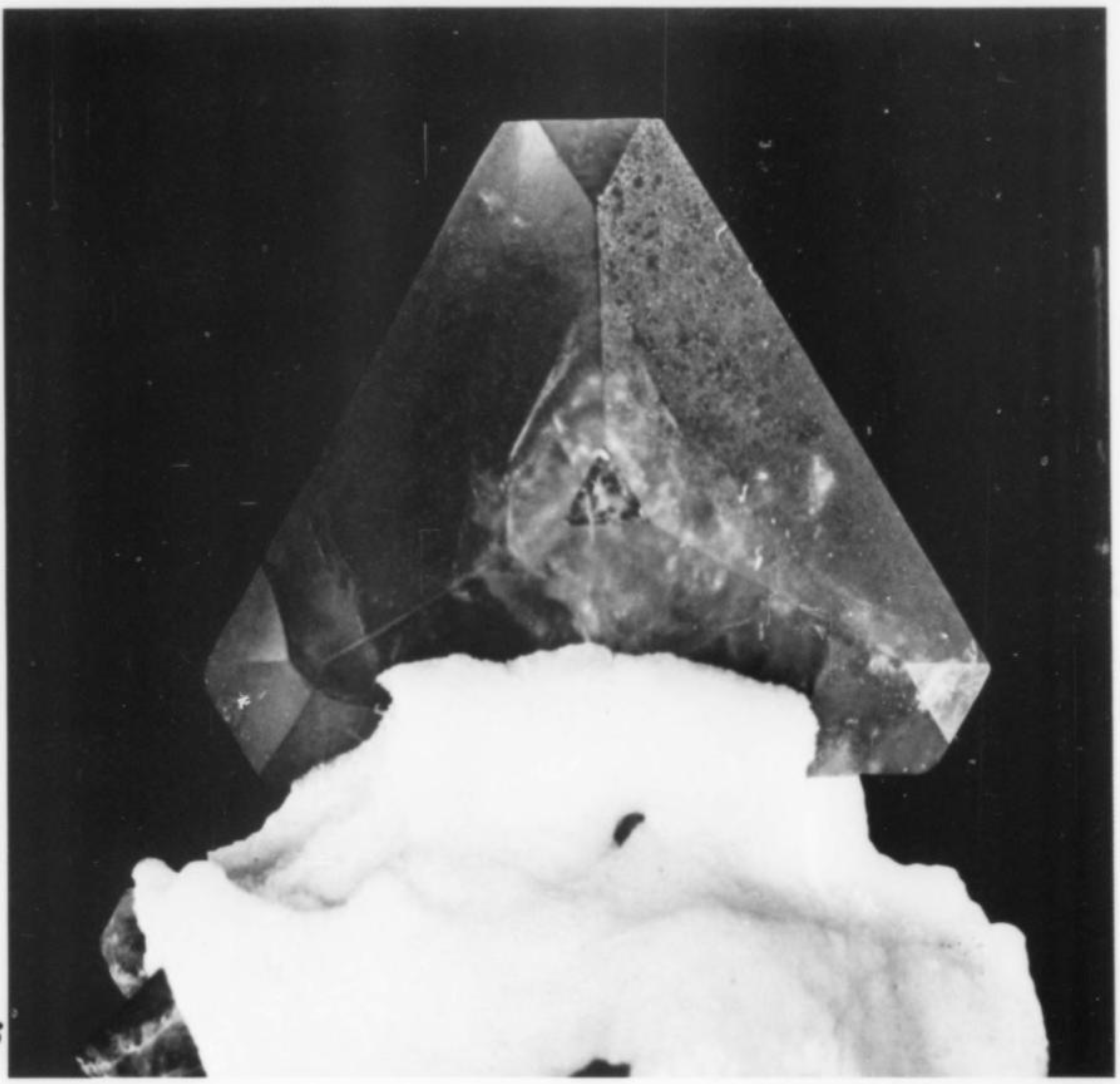


GOLD

crystals to ¼ inch in a 1⅞-inch group from the

Colorado Quartz mine, Mariposa County, California.

Collection of David Eidahl; photo by Harold and Erica Van Pelt, photographers, Los Angeles.



Minerals of the BENITOITE GEM MINE

by William S. Wise and Robert H. Gill, Department of Geological Sciences
University of California, Santa Barbara, California 93106

Figure 1. (top) **A triply terminated benitoite crystal 2 cm wide, on a matrix of natrolite. R. Gill specimen; photo by Harold and Erica Van Pelt, Photographers, Los Angeles.**

Figure 2. (above) **Panoramic view of Joaquin Ridge and the Benitoite Gem mine (recent photo).**

Figure 3. **The Benitoite Gem mine in its early days. This view shows the open cut, the drift portal (center background) and the incline with ore bucket to the left. The present open cut extends 5 metres farther into the wall and 3 metres lower. This photograph was first published in the *California Journal of Mines and Geology*, 1938.**

INTRODUCTION

THE mention of Benitoite Gem mine[1] brings to the minds of most mineral enthusiasts specimens of benitoite, neptunite, and joaquinite. To those who have visited the locality, the Benitoite Gem mine is one of several interesting mineral localities in the dry, brush-covered slopes of the southern Diablo Range (Fig. 2). Compared to other famous mineral localities in the world, the Benitoite Gem mine stands out, not for the variety of its minerals, but for their rarity and superb crystal quality.

The three major minerals—benitoite, neptunite, and joaquinite—were described by Prof. George Louderback in 1909 in a classic paper, one of the finest descriptions of a new mineral ever written. Benitoite caused an immediate sensation, partially because of the attractive gems cut from it and also because it was the first mineral found to be in the crystal class 6m2. Neptunite, although not a new mineral, was found in fine crystals with a habit somewhat different from those already known from Greenland. Joaquinite was to remain incompletely described until only a few years ago.

This article will review the geology, mineralogy, and origin of the deposit. The chemistry, crystallography, and physical properties of the major minerals will be reviewed and illustrated with all new photographs. New data will also be presented on the copper sulfide minerals, which have important implications on the origin of the deposit.

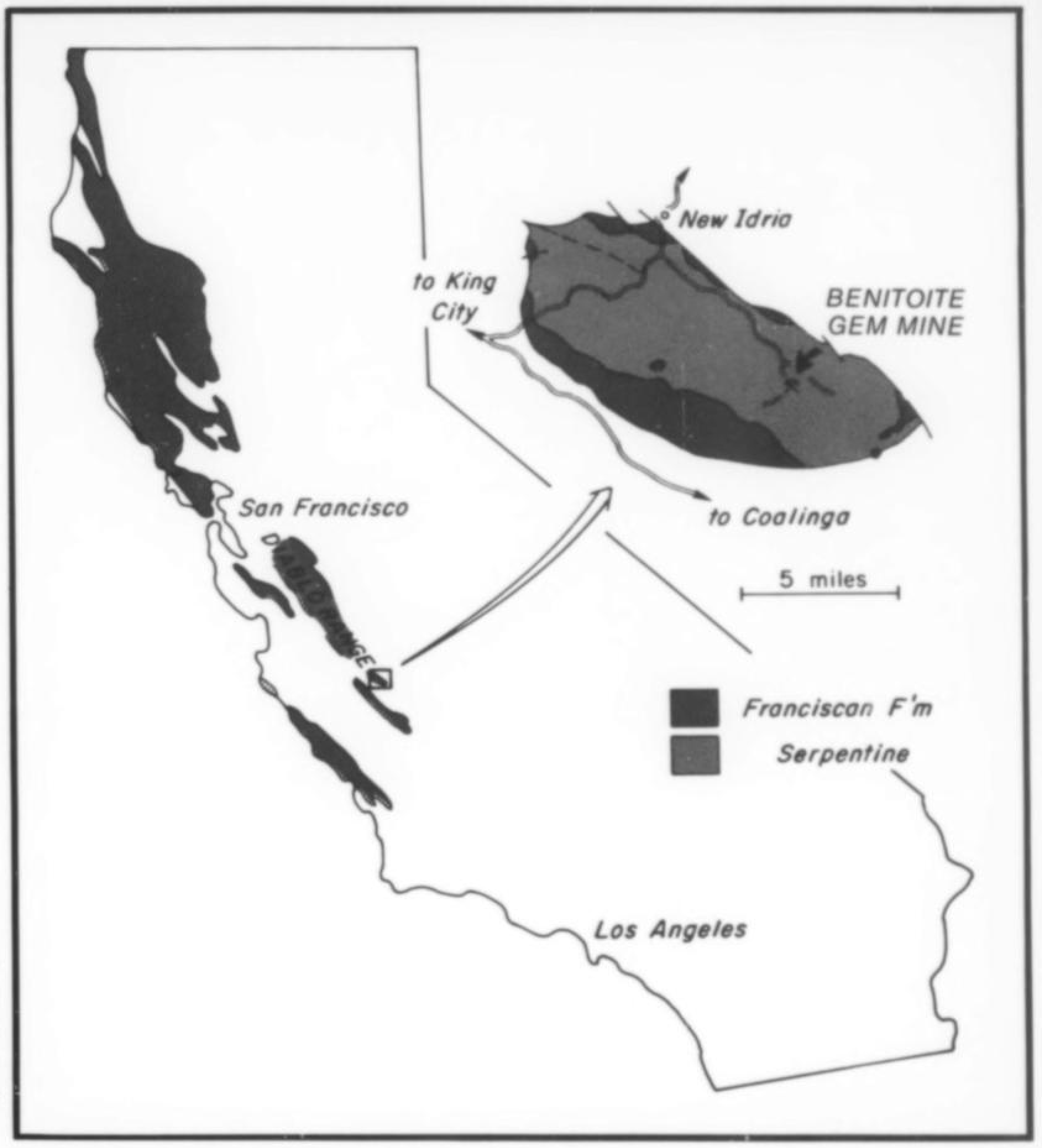


Figure 4. (above) **Location map showing general geology, the New Idria serpentine body and the Benitoite Gem mine.**

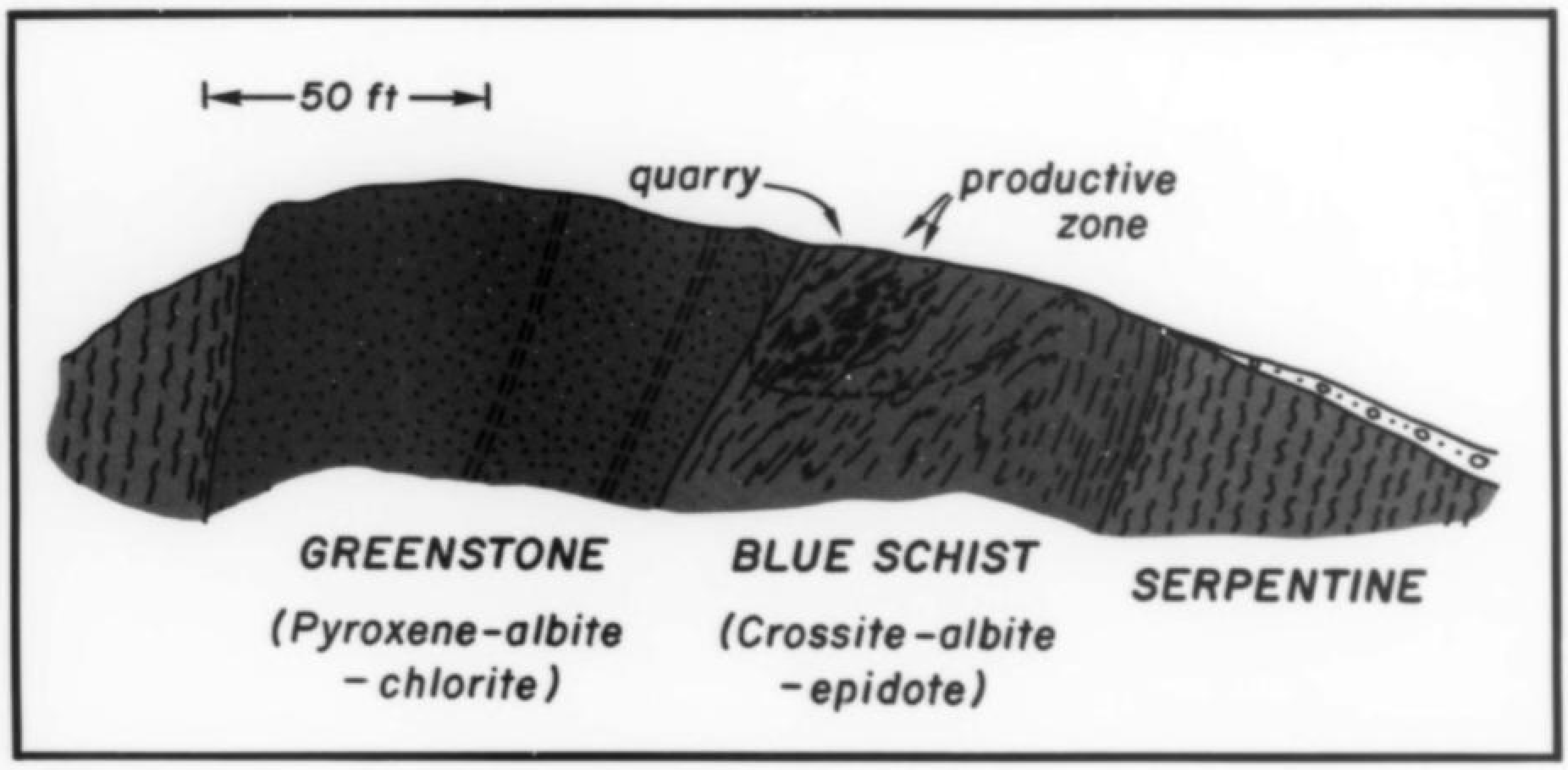


Figure 5. (left) **Cross-sectional diagram through the block of metamorphosed Franciscan rocks in which the Benitoite Gem mine is located. The drawing is based partially on the work of Sterret (1911) and Coleman (1957).**

THE SETTING

The Benitoite Gem mine is located at the southern end of the Diablo Range, a belt of mountains along the west side of California's San Joaquin Valley (Fig. 4). The range is built of rocks of the Jurassic Franciscan formation (graywacke, shale, chert, and basalt) and serpentine with Cretaceous and Tertiary sandstones. Throughout much of the range the Franciscan rocks are metamorphosed to high pressure, low temperature mineral assemblages which include jadeite, lawsonite, glaucophane, and aragonite. The Franciscan rocks are intimately associated with serpentine. Moreover, these rocks have been repeatedly deformed since the Jurassic Period, so that the units have locally been broken and intermixed. One of the largest blocks of serpentine in the Diablo Range occurs in the New Idria district (Fig. 4).

---

[1] The mine has been variously called "Benitoite Gem mine," "Benitoite mine," "Gem mine," "Dallas Benitoite mine," and "Dallas Gem mine." Since the U.S. Geological Survey topographic maps label the locality as "Gem mine," we have chosen to modify this name with the gem mineral. Moreover, "Benitoite Gem mine" is the name used by the current lessees, E. Gray and W. Forrest.

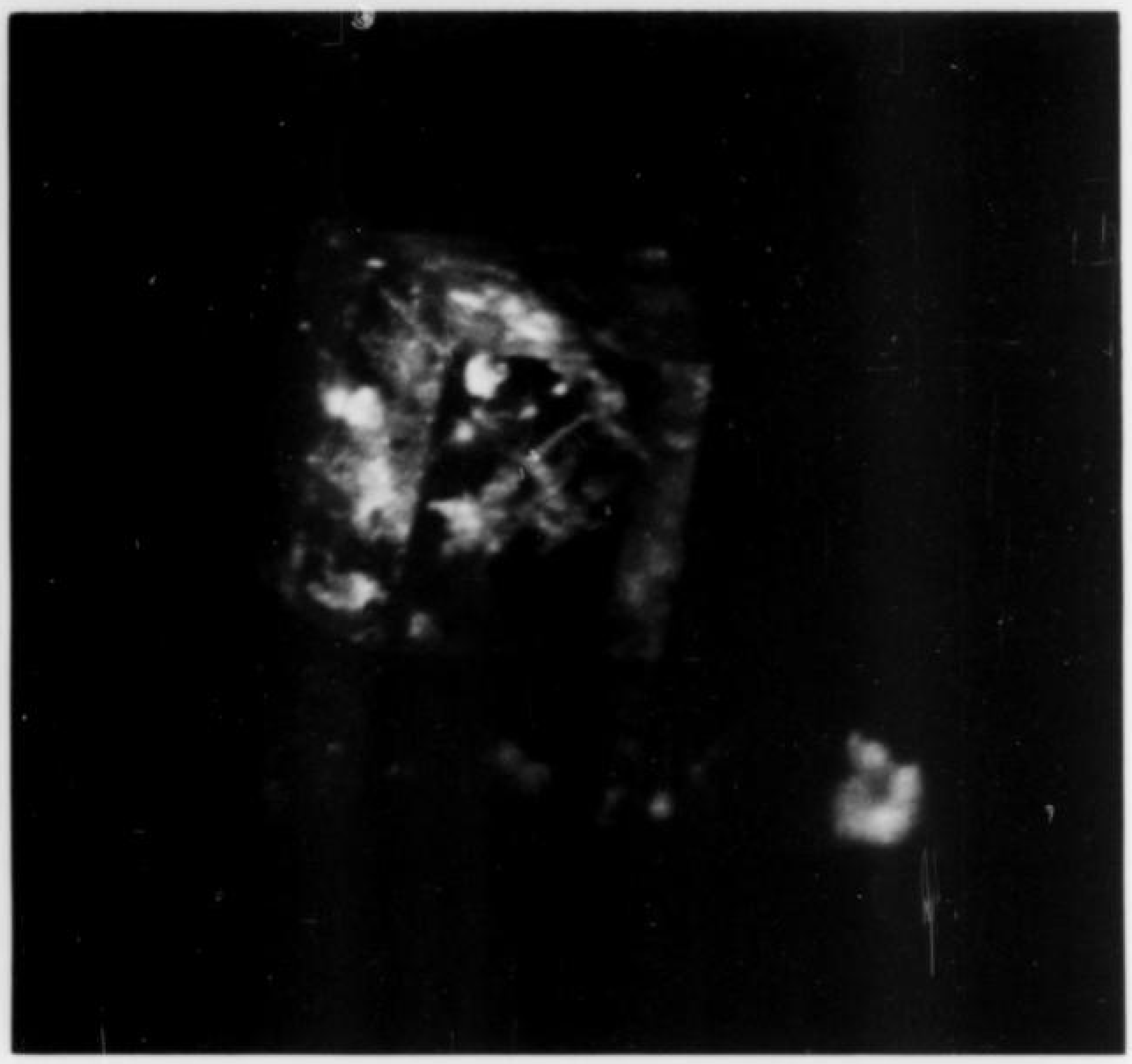


Figure 6. **Joaquinite crystal, about 1 mm in size, on the face of a lustrous, black neptunite crystal. R. Gill specimen and photo.**

Within its 13-mile length are several slabs of metamorphosed Franciscan rocks up to a half mile long.

During the time that the New Idria serpentine block has been in place there have been periods during which solutions percolated through fracture systems. These fluids have brought about emplacement of cinnabar and metacinnabar at New Idria, altered serpentine to calc-silicate assemblages (these include melanite and topazolite garnet, diopside, and vesuvianite), reacted with serpentine to form coalingite and artinite (see Cisneros, Witkowski and Oswald, elsewhere in this issue), and altered some of the Franciscan blocks. The Benitoite Gem mine is located in one of these blocks.

Figure 5 is a representative cross section through the Franciscan block in which the veins containing benitoite, neptunite, and other minerals have formed. The block is composed of greenstone (metamorphosed graywacke) and blue-schist (metamorphosed basalt). Veins occur in a brecciated zone in the schist, which is composed largely of albite, crossite, and epidote. The schist was not only crushed, but was converted in many places to soft, felted masses of actinolite or crossite fibers. Benitoite, neptunite, joaquinite and other minerals formed in the cavities and filled pore spaces in felted amphibole. The crystals that grew in the cavities are well formed with the characteristic colors associated with the minerals, while those that included crossite or actinolite have a dull, porous appearance with their colors tinted by the amphibole. Other minerals that formed at about the same time include albite, apatite, jonesite, and the copper sulfides djurleite and digenite. At a later stage natrolite partially to completely coated the earlier-formed minerals and filled much of the remaining pore spaces in the crossite rock. Natrolite also filled a number of barren fractures, forming veins several feet wide.

DISCOVERY AND DEVELOPMENT OF THE MINE

The discovery of the deposit is in some dispute, especially with regard to the discoverer. Sterrett (1911) states *"It is evident that J. M. Couch of Coalinga, grubstaked by R. W. Dallas, was instrumental in finding the deposit. Whether he discovered it while out alone or on a second trip with L. B. Hawkins of Los Angeles, is a point in dispute. Material taken to Los Angeles by Mr. Hawkins was pronounced volcanic glass and valueless. According to Mr. Couch* [see Couch, 1961], *specimens given to Harry U. Maxfield of Fresno were shown to G. Eacret of Shreve & Co., San Francisco and to G. D. Louderback. Specimens cut by Mr. Eacret were thought to be sapphire. Professor Louderback found the material to be a new mineral and named it benitoite*

Figure 7. **Neptunite showing its true red color, perched on a yellow-brown joaquinite crystal about 1 mm in size. R. Gill specimen and photo.**

Figure 8. (left) **Benitoite (blue) with joaquinite (yellow-brown) on crossite matrix; the benitoite crystal is about 1 mm. R. Gill specimen and photo.**

Figure 9. **Benitoite dipyramids with typical white core and blue edges, on a specimen from which the natrolite has been partially etched away. Each crystal is 4.1 cm on edge. R. Gill specimen and photo.**

after the county in which it was found."[2]

Dallas formed a company and between 1907 and 1912 actively mined the veins for benitoite gem material. He patented two claims, covering 40 acres, which have remained the property of Dallas and his heirs.

The veined schist was exposed by a small pit about 25 metres long, 6 metres wide, and up to 8 metres deep. An exploratory drift and incline were also dug with little veined schist found (Sterrett, 1911). The veins were opened, and the benitoite liberated from the enclosing natrolite at first with chisels and a punchpress. A great many crystals were destroyed by this process before it was discovered that the natrolite could be dissolved by acid[3] treatment. However, the process was too slow, and they went back to breaking crystals from the rock.

From 1912 until 1920 the mine lay dormant; apparently the world war disrupted the market for the gem stones. The mine was leased by Dallas to B. Suit of the San Benito Gem Company, but little mining was done until 1933. At that time the mine was reopened and M. Dunn removed considerable material. During the early 1950's M. F. Hotchkiss leased the property. He principally bulldozed the old dump, looking for large blocks of the veined blue-schist. C. L. Cole took over the lease from about 1952 until 1967. He reopened the pit, burying a portion of the original dump with newly mined rock. For a limited time in 1966, J. Scripps and G. Bosley sublet the mine from Cole and enlarged the pit, completely burying the original dump. In 1967 when E. Gray and W. Forrest took over the lease, the pit was at the same depth as in 1912. They enlarged the pit both laterally and in depth, cutting into new veined blue-schist.

All of the superb neptunite specimens were mined from veins in the open cut by Gray and Forrest between 1968 and 1970. There were very few exceptional benitoite specimens recovered from these veins. A large block with numerous natrolite veins filled with neptunite was mined from the open cut in the spring of 1970 (see Fig. 1 in Wise, Pabst, and Hinthorne, elsewhere in this issue). All of the known jonesite specimens except for one were from this block as well as several exceptional neptunite specimens. Future production from the open cut veins is doubtful, because the remaining veins do not appear to contain any benitoite or neptunite.

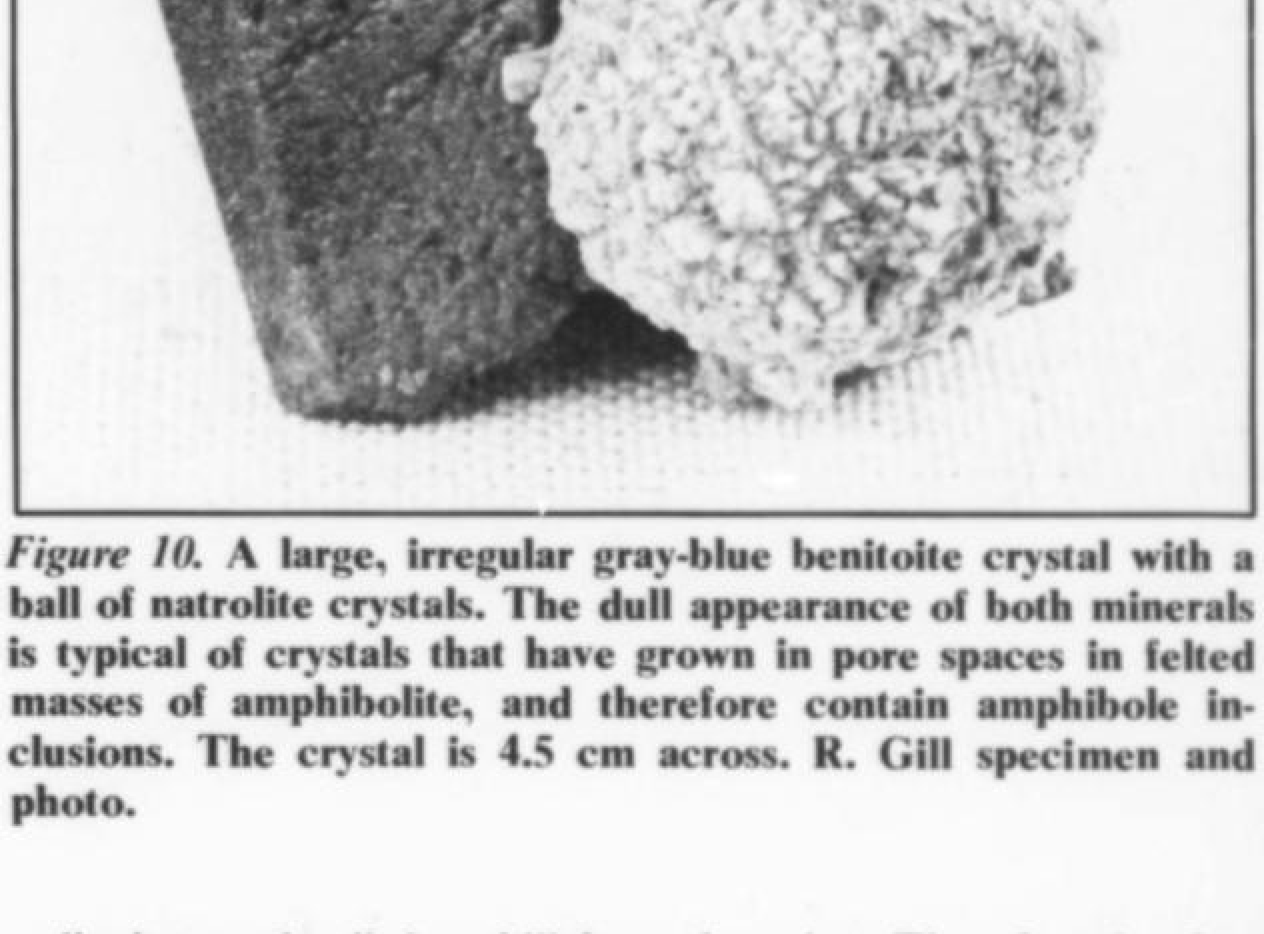


Figure 10. **A large, irregular gray-blue benitoite crystal with a ball of natrolite crystals. The dull appearance of both minerals is typical of crystals that have grown in pore spaces in felted masses of amphibolite, and therefore contain amphibole inclusions. The crystal is 4.5 cm across. R. Gill specimen and photo.**

In recent years Gray and Forrest have worked through the colluvium and soil downhill from the mine. They found a few superb benitoite specimens and a fair quantity of good benitoite and neptunite specimens, as well as gem material. Only one exceptional neptunite specimen was recovered from these deposits (Fig. 19). The entire colluvium deposit has been mined and only limited production is expected in the future.

---

[2] Louderback apparently named the mineral after both the San Benito River, which has its headwaters very near the deposit, and the county (Louderback, 1907, p. 149).

[3] *Ed. Note:* Hydrochloric acid may be used to dissolve natrolite without harming benitoite, neptunite, joaquinite or jonesite. Concentration is not especially critical, although the natrolite will dissolve more rapidly in more concentrated solutions. Cold, concentrated hydrochloric acid will remove about 0.5 mm of natrolite per hour. The reaction can be further speeded up by heating the acid, a procedure which also increases the danger associated with handling acids. Unfortunately the crossite matrix, often minutely impregnated with natrolite will also tend to dissolve, and may have to be wax-coated to prevent this; however saw-cuts can be rendered unnoticeable by allowing the acid to eat away the smooth cut surface on the matrix.

During acid treatment the natrolite will react, leaving a transparent silica gel which is easily brushed away periodically. When acid etching is complete the final vestiges of silica can be removed from the specimen by a quick rinse in a strong base, such as lye (sodium hydroxide), potassium hydroxide, etc. Here again, a hot solution will react more rapidly but is more dangerous. Wax may be removed by soaking in carbon tetrachloride.

Figure 11. A large (4.0 cm), irregular crystal of benitoite with crossite inclusions and two small balls of natrolite. R. Gill specimen and photo.

Even though good specimen material was produced by various operators of the mine, the specimens being produced by Gray and Forrest are probably the best. It is not because they have found better material but because of the care and technique with which they remove some of the natrolite from the specimens.

Good quality gems cut from benitoite are seldom larger than one carat. Gems over 2 carats are rare with only a few in existence over 3 carats. The largest known faceted clear benitoite is 7.5 carats and is in the gem collection at the U.S. National Museum. Gray and Forrest made a set of benitoite jewelry, consisting of a necklace, a ring, and earrings. The necklace had a pendent portion with a 6.53 ct pear shaped faceted benitoite. The Jewelry was shipped to Zürich, Switzerland, where it was stolen from the airport. After nearly a year the jewelry was recovered. However, the pendant portion of the necklace is still missing.

THE MINERALS

Benitoite

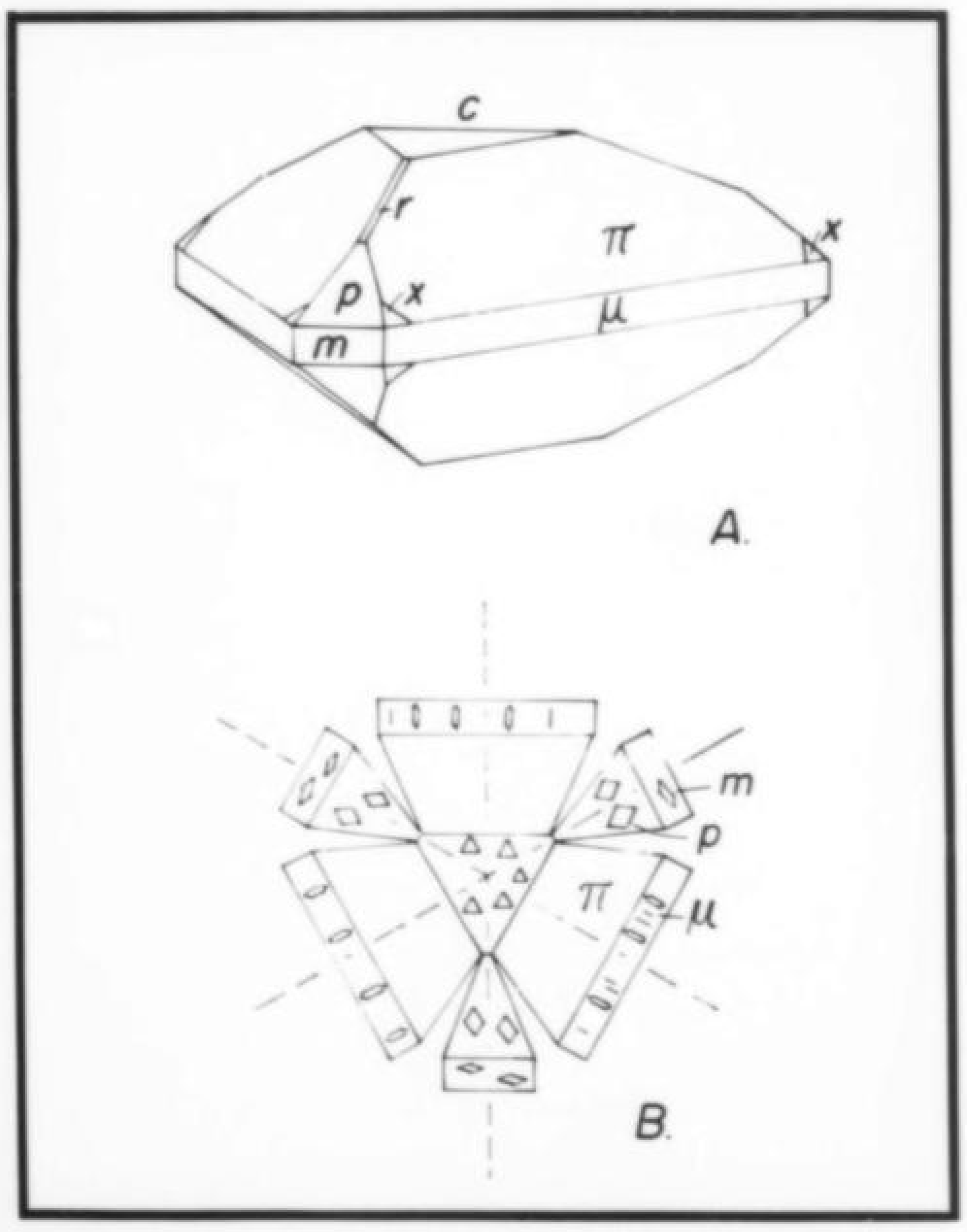
Crystals of benitoite commonly have white cores and deep blue outer margins (see cover photo and Figs. 1 and 9). Detailed electron microprobe work by Laird and Albee (1972) on the white and blue parts of benitoite crystals indicates that the composition is very close to stoichiometric $\mathbf{BaTiSi_3O_9}$ in both parts. A small amount of iron (0.05%), detected by emission spectroscopy in the deep blue material, may be the chromophor.

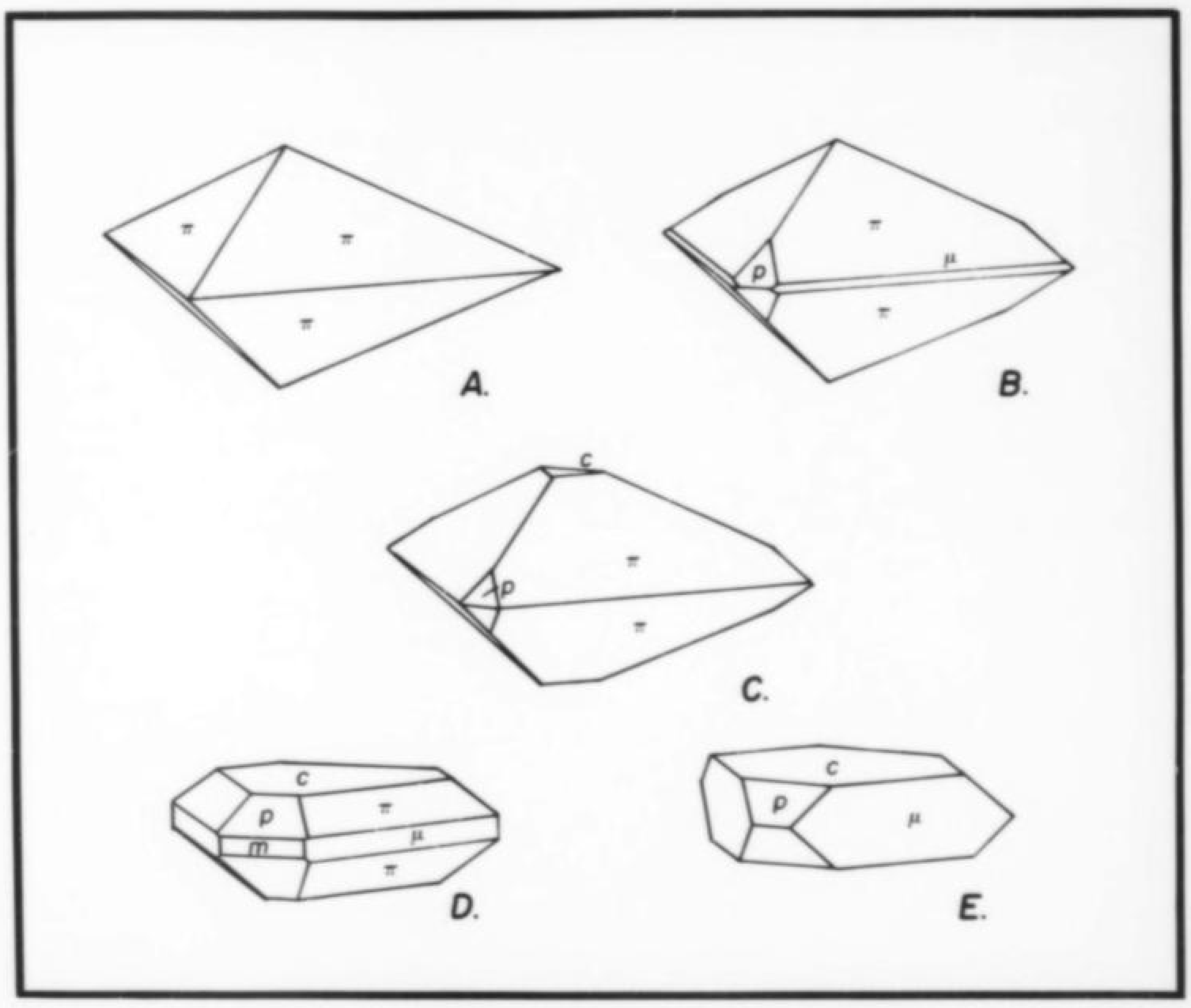
The appearance of crystals of benitoite varies widely. A few are gemmy and deep to pale blue. The large majority are translucent with white centers and blue outer rims. Crystals that have a stoney appearance are pale blue-gray because of abundant crossite inclusions. Some of these crystals have irregular forms with etch pits and multiple faces or edges (Fig. 10). As far as we know the largest well-formed benitoite crystal is 5.6 cm and is in the collection of the Geology Department of Pomona College, California. Crystals 2.5 cm across are generally considered large, and average sizes are in the range 1 to 1.5 cm.

The basic dipyramids are commonly attached by one of the three corners or edges, although "triply terminated" crystals are not especially rare (see cover and Fig. 11). The descriptions of the crystal forms by Louderback (1909) were well done. In order to prove that benitoite belonged to the ditrigonal-dipyra-

Figure 12. *(below) (A)* Common forms of benitoite; the forms are *c*{0001}, *π*{0111}, *μ*{0110}, *p*{1011}, *m*{1010}, *r*{1012}, and *x*{10.1.9.10}. *(B)* Exploded diagram of the faces of a benitoite crystal showing their etch patterns. The artificially produced etch figures demonstrate that the *π* and *p* faces are not related to the *μ* and *m* faces by symmetry, thereby showing the existence of a 6 axis rather than a 6 axis. (Both figures from Louderback, 1909, plate 37).

Figure 13. *(below right)* Some variations in benitoite habits. The sequence shows the *π* face decreasing in importance.





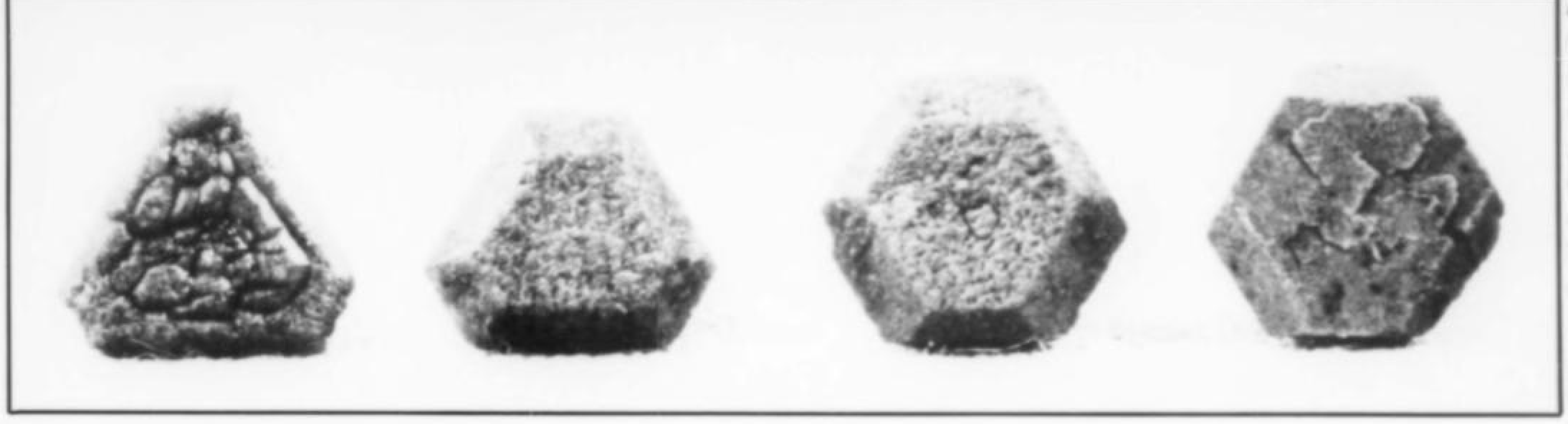


Figure 14. **Four benitoite crystals with dominant *c* faces and a variety of pyramid and prism faces. All crystals are about 1.2 cm high and are heavily filied with crossite inclusions, making them a dull gray-blue in color. R. Gill specimens and photo.**

midal class ($6m2$), he had to make a careful study of etch figures on the faces. One of his crystal drawings and the results of the etch figure study are reproduced in Figure 12. The etch figures demonstrate that the *p* and π faces are symmetrically unrelated, proving the existence of a 6 axis. The atomic arrangement determined by Zachariasen (1930) confirmed Louderback's conclusions.

The luster of the various forms also conforms to the crystal symmetry. Louderback (1909, p. 346-347) noted that the negative pyramids (π faces) show various degrees of dulling, while *p* faces are commonly, but not always, bright. The *c* and μ forms are always bright. These luster differences between the forms apply to crystals that have not been in acid baths for natrolite removal. The frosty appearance seems to be a result of minute etch pits, not imperfect face growth. Since the *c*, μ, and *p* forms are artificially etched only with prolonged exposure in hot acid, Louderback concluded that the dullness of the π faces is the result of natural etching, possibly at the time of natrolite deposition.

Considerable variation exists in the shapes of the crystals. We have found no forms that Louderback did not recognize, but illustrate in Figure 13 a number of variations on the basic shape, caused by the dominance of one form or another. Dipyramids with no *c*-face occur with varying degrees of complexity. Crystals with prominant *c*-faces form plates that are either trigonal or hexagonal, depending on the relative development of *p* and π faces (Figs. 13 and 14). Some flat, stoney crystals have multiple faces π and *c* on the basal plane. Unusual shapes occur when some forms, like μ become over-developed. A few crystals have been found that are elongated parallel to one edge.

Most benitoite crystals are blue and strongly dichroic (colorless to deep blue). The deepest color is for light vibrating parallel to the *c*-axis. A gem cut with the table perpendicular to the basal plane will yield the deepest color, while those cut at angles to this orientation will display weaker colors. The color of faceted benitoite varies from a very pale blue through a rich blue to a deep purplish blue. Colorless gems are uncommon. A very few gems have a strong reddish component, giving various shades of rose to heliotrope. These reddish gems, which have a pink to blue dichroism, came from portions of crystals which otherwise showed normal color variations for benitoite. Small (2mm) pink benitoite crystals were reported from an undisclosed locality by Chromy (1969). This locality is now known to be **Mina Numero Uno** (Sharon Cisneros, pers. comm. 1976). The cause of the color and color variations is still under investigation (Rossman,

Figure 15. (left) **Dark blue benitoite crystal perched on a neptunite crystal. The benitoite crystal is 1.6 cm across. Wendell Wilson specimen and photo.**

Figure 16. (below) **A blue benitoite crystal on blue-schist; the specimen is 5.4 cm across. R. Gill specimen and photo.**

Figure 17. **Stacked, deep blue, lustrous benitoite crystals on blue-schist matrix. The largest crystal is 2.7 cm across. R. Gill specimen and photo.**

pers. comm. 1976).

Benitoite fluoresces blue-white under ultraviolet light, but displays some interesting variations, especially in the crystals with the white cores and blue margins. Under short wave ultraviolet light the white cores fluoresce brighter than do the blue edges, and under long wave ultraviolet light the white cores fluoresce dull red, while the rims are non-fluorescent.

Neptunite

Neptunite was first found in Greenland, and San Benito County was the second location. It has a composition near **$LiNa_2K(Fe,Mg,Mn)_2Ti_2Si_8O_{24}$**. The average Fe, Mg, and Mn contents are near 1.40, 0.40, and 0.20 respectively (Laird and Albee, 1972), making the San Benito neptunite considerably more iron rich than those from Mt. St. Hilaire (Canada), Greenland, or the Kola Pennsinsula. The microprobe studies of Laird and Albee (1972) showed that the only compositional variations were in the Fe, Mg, and Mn contents.

Neptunite forms prismatic crystals with lengths usually 8 times the width. These crystals are most commonly attached by one end to vein walls. Neptunite prisms from Greenland are terminated by domes {h0l} and {0kl}; both forms are lacking in the San Benito crystals. Here common terminating faces are *s* {111}, *o* {1̄11}, and *p* {311}. See Figures 18-20 and 22-24.

Neptunite forms crossing twins, similar to staurolite, with the angle between the *c*-axis near 40°. The twin plane is (301) (see Figures 18 and 21). Many neptunite crystals, including some of those that are twinned, are S-shaped rather than straight prisms (Fig. 25). These shapes apparently form by uneven growth on the *a* and *m* faces. Most rapid growth occurred on the ends of these faces near the *s* and *o* faces, and slower near the *p* faces.

To our knowledge, the largest neptunite crystal is 7.5 cm long (Gray, pers. comm. 1976, Fig. 25). Generally a crystal 4 cm in length is considered large; average crystals range up to 2.5 cm.

The shiny black color of neptunite is actually a very deep red-brown, which can be seen in small crystals or fragments. With numerous amphibole inclusions the neptunite faces lack a shiny luster, but the red-brown color is more apparent.

Joaquinite

Joaquinite (pronounced *"wah-keen-ite"*), as tiny honey-yellow to orange-brown equidimensional crystals, was noticed and briefly described by Louderback (1909). Joaquinite has the most complex composition of the Benitoite Gem mine minerals. Rare earth elements (REE) were first found in joaquinite by Semenov, *et al.*, (1967) and detailed analyses were later made by Laird and Albee (1972). Based on the structure determination of Cannillo, Mazzi, and Rossi (1972), the unit cell formula is **$Ba_4Fe_2\mathit{REE}_4Ti_4(Si_4O_{12})_4$**, where the ***REE*** consist of **Ce, La, Nd, Pr, Sm,** and **Y** (Laird and Albee, 1972).

Measurements on the crystal faces by Louderback (1909) led him to believe that the mineral was orthorhombic (Fig. 26). Cannillo, *et al.*, (1972) and Laird and Albee (1972) found that joaquinite is monoclinic but twins on (001) to form an orthorhombic cell.

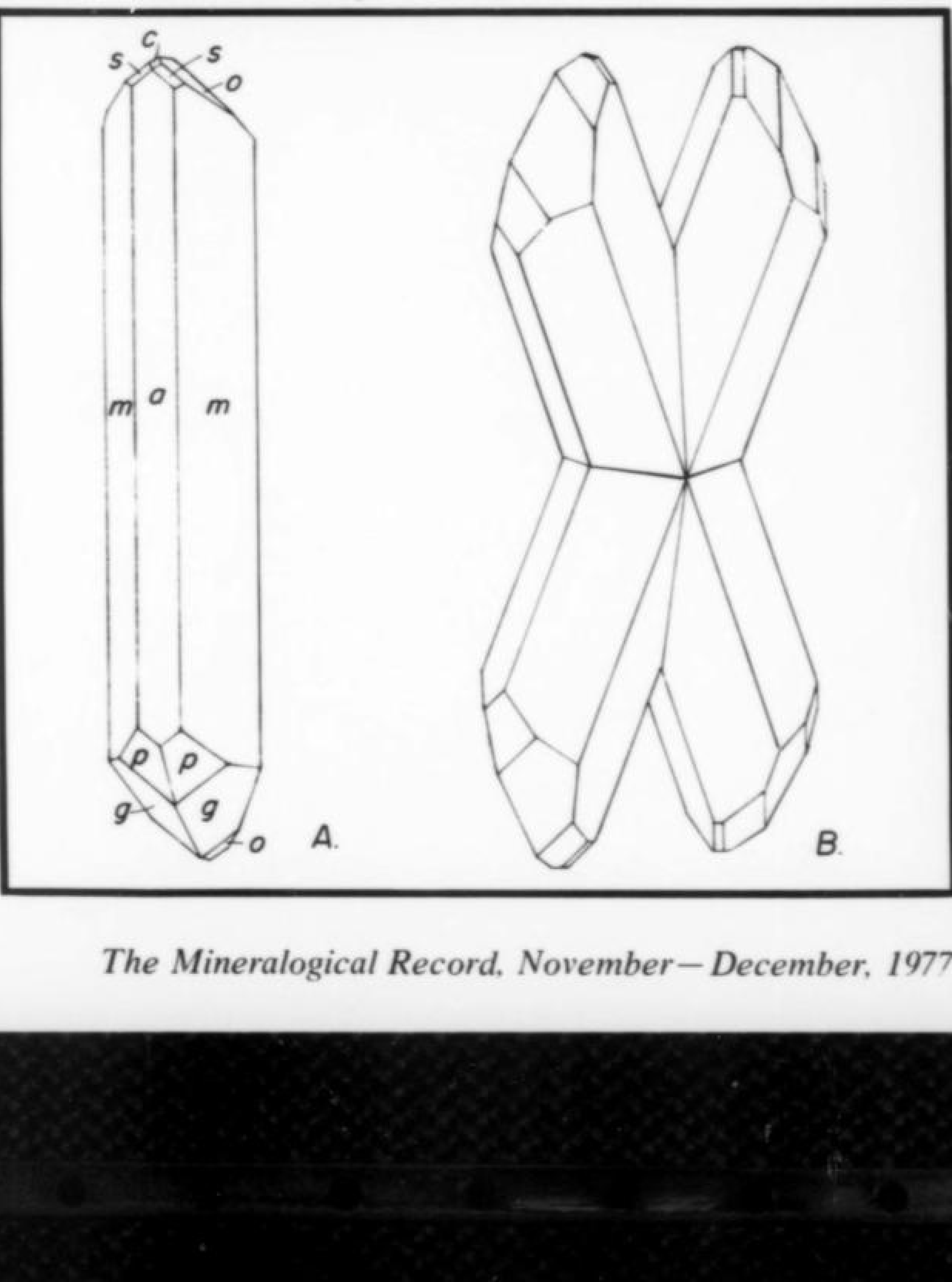
Joaquinite crystals are yellow-brown to orange-brown, and vary in length to 3 mm (see Figs. 6-8 and 27). They have been confused with anatase (reported before Louderback's description of joaquinite), which has never been verified at the Benitoite Gem mine.

Copper Sulfides

Louderback (1909) reported chalcocite as one of the original minerals in the veins, and Desautels (Murdoch and Webb, 1966, p. 169) found **digenite** as well. We have obtained a number of specimens with dull black crystals of copper sulfides.

X-ray studies of the crystals thought to be chalcocite indicate that they are **djurleite** (Potter and Evans, 1976), a low temperature form with a composition near $Cu_{1.95}S$. Our X-ray work confirmed the existence of **digenite**, but also revealed that **covellite** is present. Electron microprobe analyses of the digenite

Figure 18. (below) (A) **Crystal forms of California neptunite; the forms are *c* {001}, *a* {100}, *m* {110}, *s* {111}, *o* {1̄11}, *g* {211}, and *p* {311}. The edge between g and p is commonly rounded and indistinct.** *(B)* **Neptunite twin; the angle between the crystals is near 40°, and the twin plane is (301).**



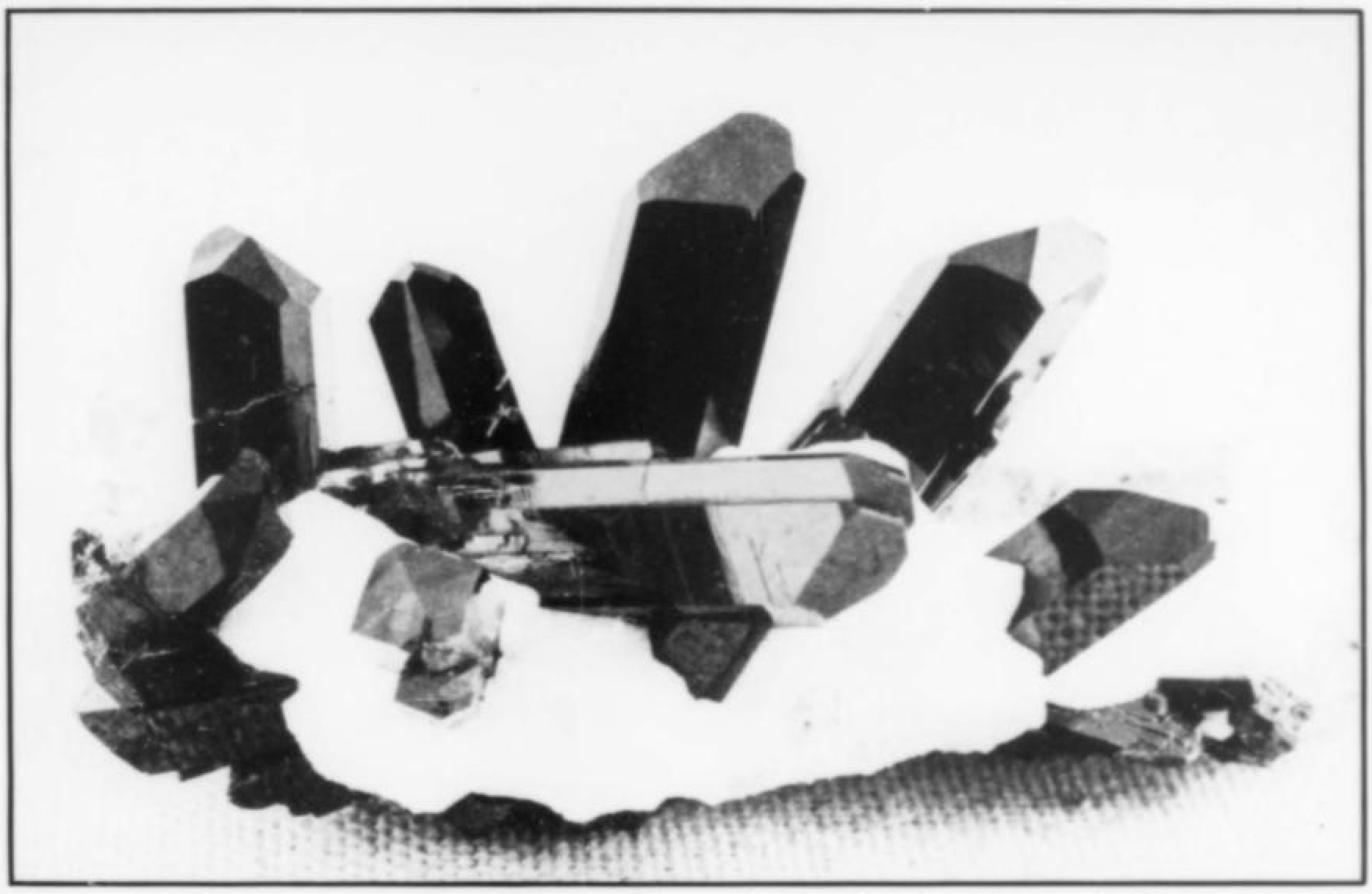


Figure 19. (above) **A group of large neptunite crystals partially removed from natrolite; specimen width is 7.0 cm. R. Gill specimen and photo.**

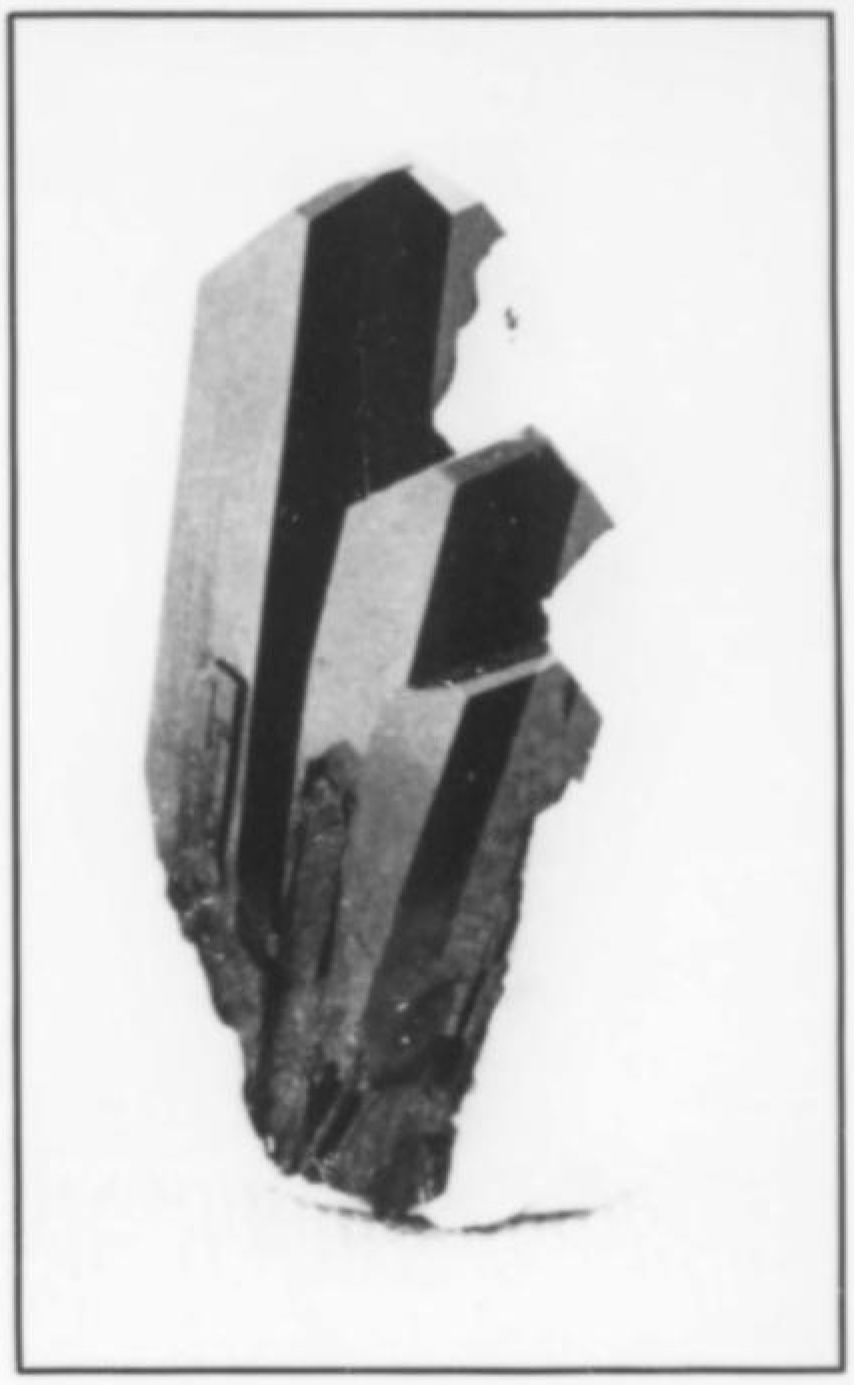
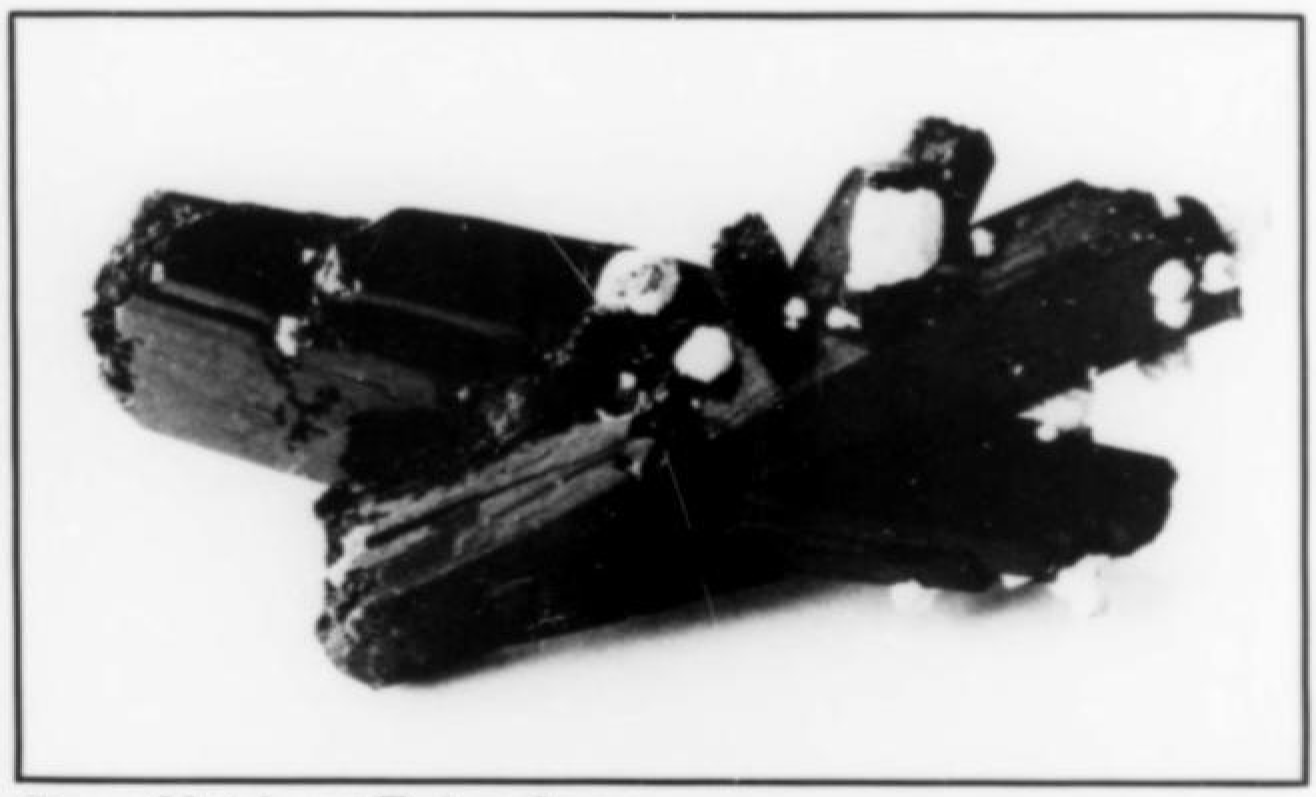


Figure 20. (right) **A cluster of three neptunite crystals with natrolite. The prominent, dark faces are *a* and the reflecting ones are *m*. Specimen height is 3.7 cm. R. Gill specimen and photo.**



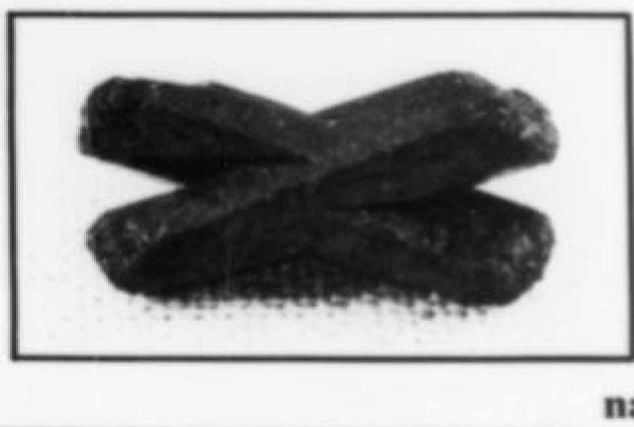


Figure 21. (above) **Twinned neptunite specimens. *(A)* with white natrolite crystals; specimen length is 6.6 cm. R. Gill specimen, W. Wilson photo. *(B)* with amphibole inclusions and dull faces. Specimen length is 2.2 cm. R. Gill specimen and photo.**

Figure 22. (above) **Doubly terminated neptunite crystal on natrolite; the crystal is 2.9 cm long. R. Gill specimen and photo.**

Figure 23. (left) **A neptunite crystal 2.0 cm tall, showing sharp *p* faces. Crossite matrix is covered with natrolite which has been partially removed by acid treatment. R. Gill specimen and photo.**

Figure 24. (right) **A 3.3 cm neptunite crystal partially removed from natrolite. Note the rounded *g-p* face. R. Gill specimen and photo.**

Figure 25. (above) **The largest known neptunite crystal, 7.5 cm long (shown actual size). The curved shape results from uneven growth on the large prism faces. R. Gill specimen and photo.**

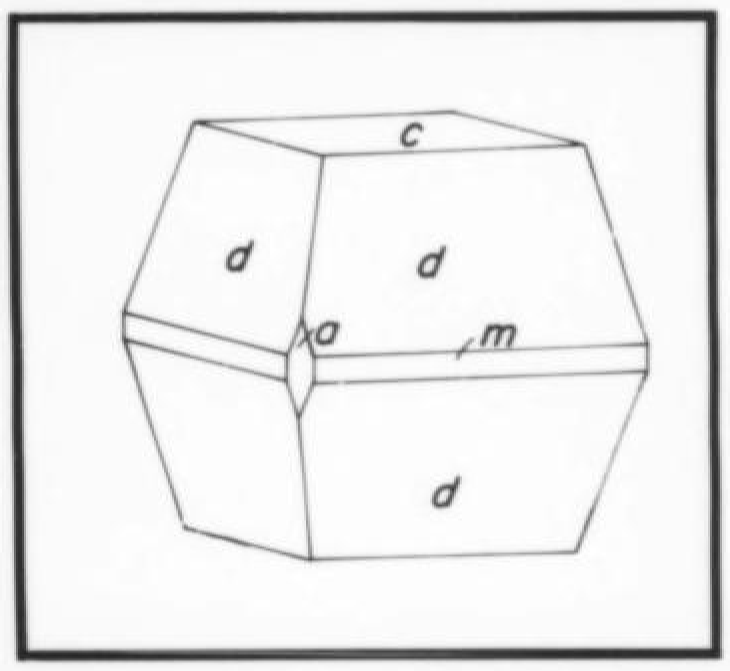


Figure 26. (left) **Crystal forms of joaquinite; the forms, based on an orthorhombic cell with c = 22.4 Å, are $c\{001\}$, $a\{100\}$, $m\{110\}$ and $d\{433\}$.**

Figure 27. (above) **Many yellow-brown joaquinite crystals to 1 mm scattered on matrix (lower half of photo) with neptunite, benitoite and natrolite. Specimen width is about 5 cm. R. Gill specimen and photo.**

give a composition of $Cu_{1.84}S$, typical for the mineral.

Djurleite crystals are generally well-formed, hexagonally-shaped dipyramids terminated with basal planes; crystals range up to 8 mm (Fig. 29). The identified crystal forms are shown in Figure 28. The *c*-faces of djurleite commonly have hexagonal pits, probably a result of incomplete growth. The much rarer digenite forms equidimensional crystals up to 9.5 mm with poorly developed faces. Most crystals are soft and show evidence of dissolution. Covellite also occurs in masses that suggest it is probably a result of alteration of djurleite or digenite, possibly during the crystallization of natrolite. (See also Fig. 8, p. 492.)

Both djurleite and digenite occur intergrown with neptunite and benitoite. **Chrysocolla** is commonly found near the crystals of the sulfides, but may have formed later, possibly at the time of natrolite deposition.

Other vein minerals

Jonesite. Occurring as small (1 mm) colorless blades on or near neptunite and joaquinite (Fig. 30), jonesite has been found on a few specimens mined in 1970. Jonesite has a composition expressed by $\mathbf{(K,Ba)_{1-2}Ba_4Ti_4Al_2Si_{10}O_{36}\cdot 6H_2O}$. An important aspect of the occurrence of jonesite is that it is not associated with benitoite. A complete description is given elsewhere in this issue.

Serandite and silica pseudomorphs after serandite. On the surface of vein walls (exposed by the removal of natrolite) cream to brownish remnants of crystals 1 to 2 mm in length are often found. These remnants are composed of amorphous silica, sometimes with Mn-oxides. Study of a rare, unaltered crystal has proven it to be a calcium-bearing serandite, $Na(Mn,Ca,Fe)_2Si_3O_8(OH)$.

Albite and apatite. Both of these minerals are fairly common in veins beyond the limits of the deposit. They occur as small (1 to 2 mm), colorless crystals. Louderback (1909) provided measurements and drawings of the highly modified albite crystals. Apatite occurs as poorly terminated, striated hexagonal prisms. Both apatite and albite have been observed associated with neptunite in a few veins.

Natrolite

Natrolite has partially to completely filled the veins. Crystals up to 2 cm in length with irregular shapes and curved cleavages form the solid masses. Where open spaces occur, allowing formation of crystal faces, the form of the aggregates are certainly not typical of natrolite. Louderback (1909, p. 358) described these forms as "...small roof-shaped ridges...commonly with curved or, more strictly, broken roof lines and coxcomb-like groups." The crystals have the tendency to align the *b*-axis at right angles to the vein wall.

Complicated groups are common, especially where natrolite fills pore spaces in felted amphibole masses (Fig. 10). Specimens of benitoite, neptunite, and joaquinite are only rarely found free of the enclosing natrolite.

Specimens of natrolite with the normal habit (*c*-axis normal

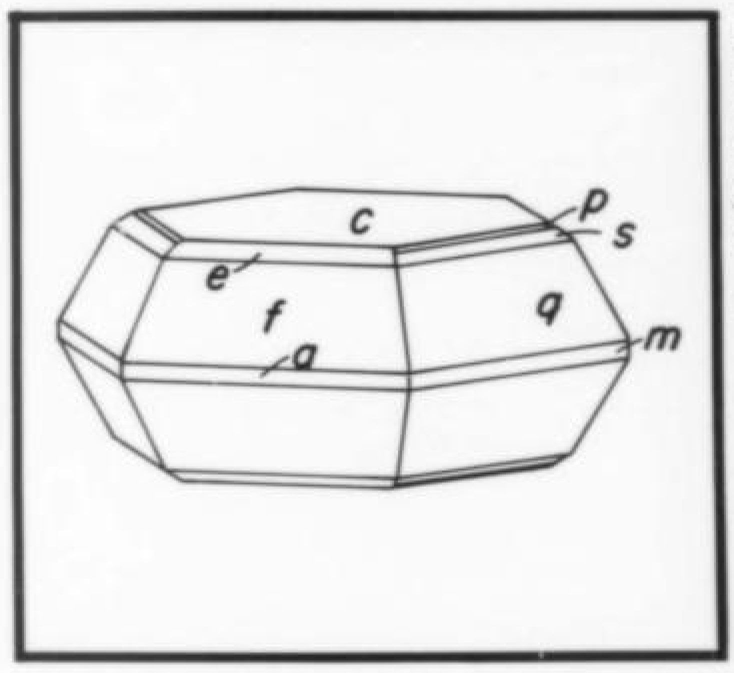


Figure 28. (left) **Crystal forms of djurleite: $c\{001\}$, $a\{100\}$, $m\{110\}$, $e\{101\}$, $f\{401\}$, $p\{112\}$, $s\{223\}$, and $q\{221\}$.**

Figure 29. (below) **Djurleite crystals attached to vein wall matrix, partially removed from natrolite. Note the rough hexagonal shapes and the pits in the *c*-faces. The diameter of the largest crystal is 8 mm. R. Gill specimen and photo.**

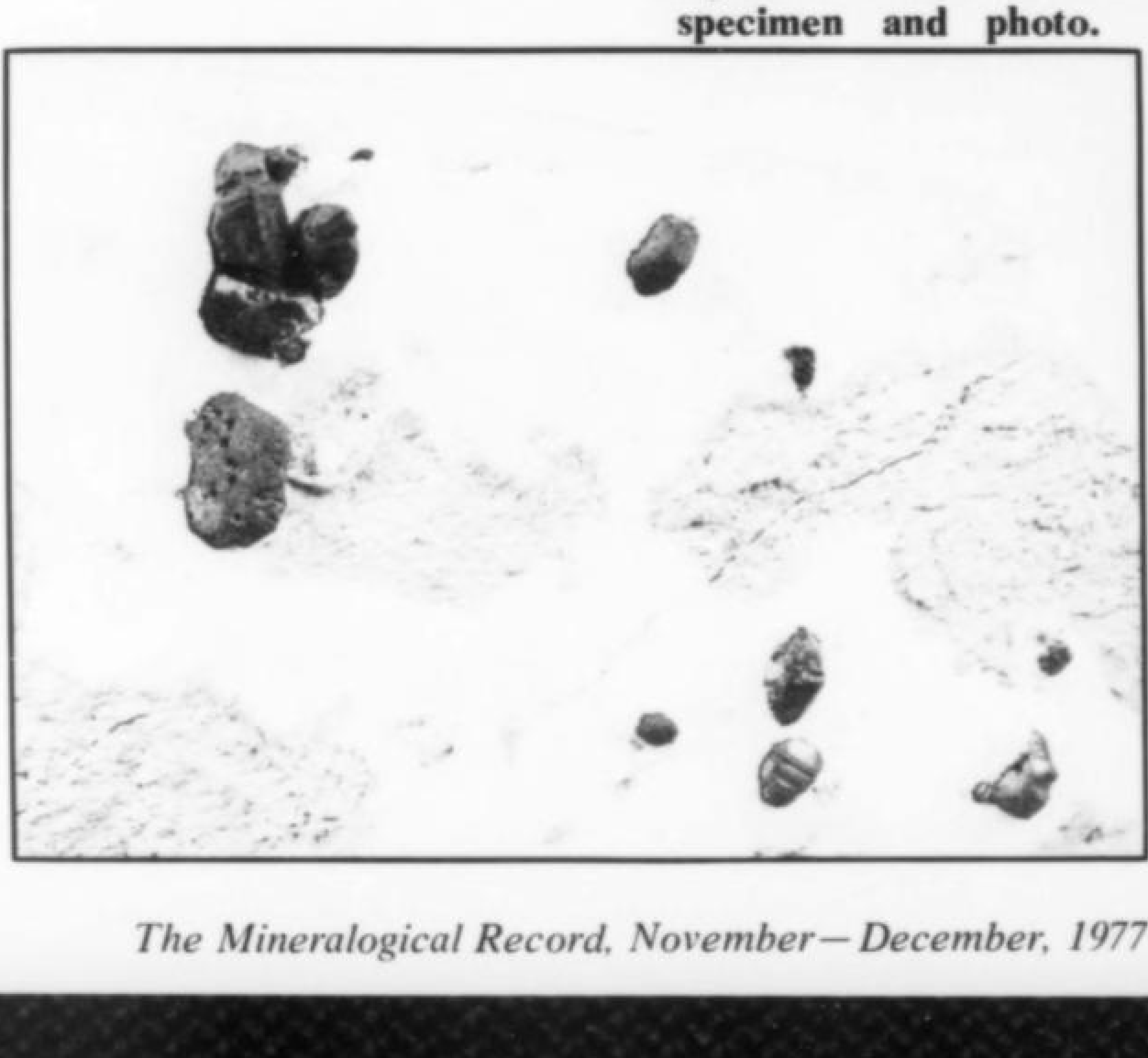


Figure 30. **Jonesite clusters (the largest is about 2 mm across) on neptunite crystals partially removed from natrolite. The neptunite crystal is 4.0 cm long. R. Gill specimen and photo.**

to the vein walls) have been found. There are several natrolite veins with this habit in the productive zone, but these veins are barren of barium silicate minerals.

Analcime has been found in one vein associated with natrolite. **Calcite** occurs in a few veins, having grown after the natrolite, never before.

Amphiboles

The felted masses of amphibole on or near the vein walls are commonly green fibers but there are many examples of blue masses as well. As Louderback (1909, p. 360) noted, the green fibers are **actinolite** and the blue are **crossite.** He used the term crossite because the iron content was too high for glaucophane.

We have obtained electron microprobe analyses of both of these amphiboles, and have confirmed Louderback's identifications. Moreover, the Fe/Mg ratio is variable, even within a single fiber.

SEQUENCE OF CRYSTALLIZATION

Our interpretation of the sequence of mineral formation (Fig. 31) differs from that given by Louderback (1909, p. 367-8) who believed that natrolite filled the veins early with benitoite and neptunite having to grow in the natrolite later. The following observations are the basis of Figure 31.

The meta-basalt near the fractures had been converted to albite, crossite, and actinolite before any vein filling, because the amphiboles are the same, whether forming vein walls or inclusions in the later minerals. Albite, apatite, and the serandite pseudomorph having grown on the vein walls occur as inclusions in neptunite and benitoite. Djurleite occurs included in or covered by neptunite and benitoite as well as in the reverse relationship. Benitoite, neptunite, and joaquinite grew nearly simultaneously because jaoquinite has been found embedded in benitoite and neptunite, as well as growing on the surfaces of these minerals (Fig. 6), and neptunite is commonly included in benitoite, though the reverse is rare. Moreover, two simultaneously growing, adjacent crystals will leave indentations in each, when broken apart. Such relations have been observed between benitoite and neptunite and between neptunite and joaquinite. Even though jonesite grows only on vein walls or on neptunite, it is probably the last to form.

Natrolite is known to have filled the veins at a later time, because none of the other minerals contain natrolite as inclusions. Some "floating" crystals of benitoite, joaquinite, and neptunite have been interpreted as indicating simultaneous crystallization of natrolite and these minerals. However, in our specimens these "floating" crystals can commonly be shown to be attached to the vein walls by an amphibole fiber.

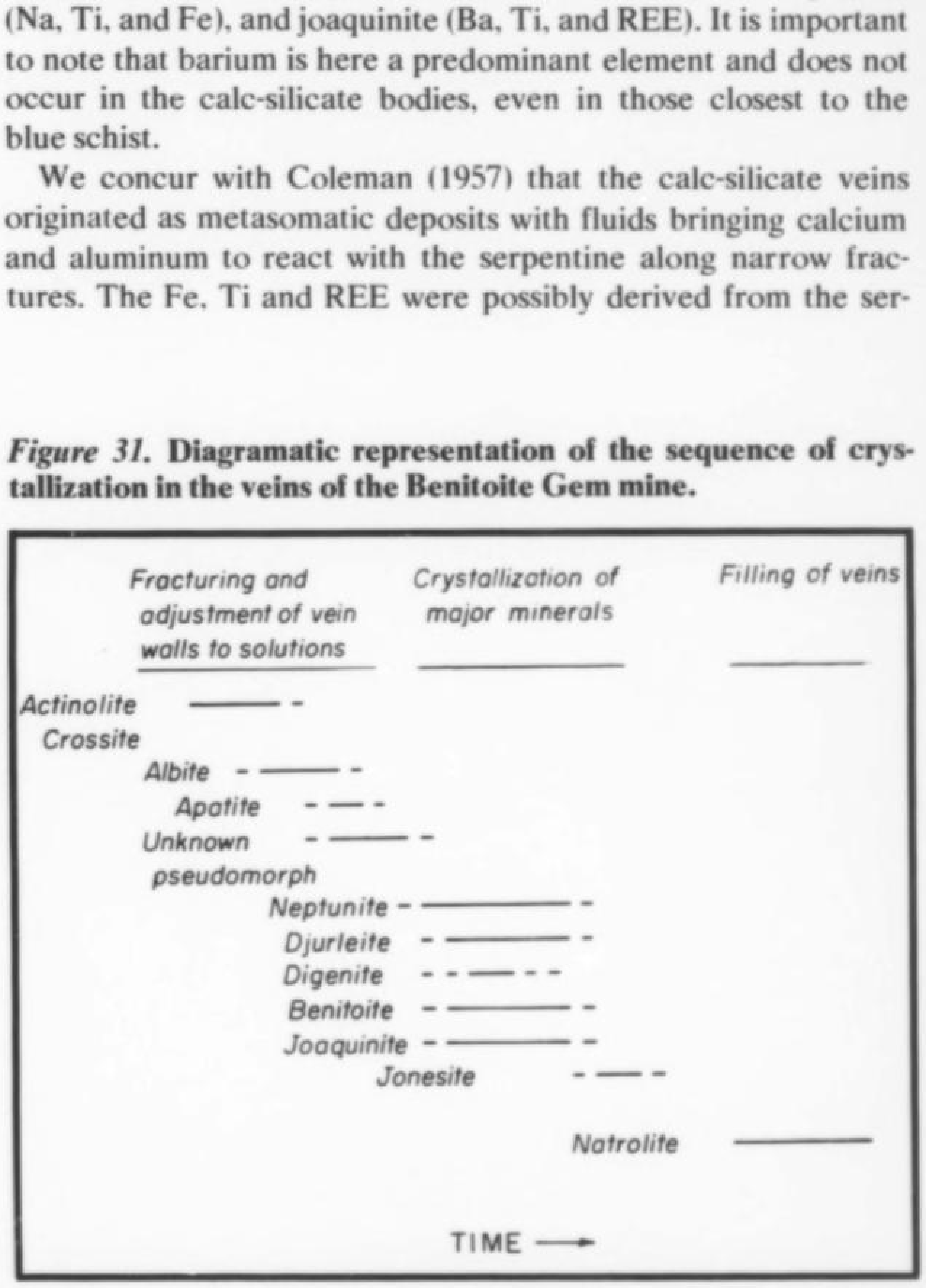
ORIGIN OF THE VEIN MINERALS

The origin of the vein minerals preceding the natrolite is best appreciated in the context of the mineralogy of the New Idria serpentine body. Benitoite occurs in at least two other masses of Franciscan rocks within the serpentine body (approximately 6 miles to the west). The larger is being mined by Eugene and Sharon Cisneros at Mina Numero Uno. Benitoite, neptunite, and a joaquinite-like mineral occur as micro to small crystals with albite in open veins or fractures in blue-schist. There is essentially no natrolite in the veins. The veins are fairly abundant and occur over several hundred feet in the blue-schist. The other is a newly discovered deposit containing small amounts of benitoite and walstromite (Gordon Brown, personal communication, 1976). In both cases the host rock, as at the Benitoite Gem mine, is a metamorphosed basalt.

Scattered in the serpentine are small calc-silicate vein complexes composed of chlorite, andradite garnet (melanite and topazolite varieties), diopside, and vesuvianite (for descriptions see Coleman, 1957, and Pabst, 1951). In some of the vein complexes iron, titanium, and the rare earth elements are concentrated in perovskite, Ce-rich vesuvianite, and the Fe and Ti-rich garnets. The veins cutting the meta-basalts similarly contain minerals rich in these elements: benitoite (Ba and Ti), neptunite (Na, Ti, and Fe), and joaquinite (Ba, Ti, and REE). It is important to note that barium is here a predominant element and does not occur in the calc-silicate bodies, even in those closest to the blue schist.

We concur with Coleman (1957) that the calc-silicate veins originated as metasomatic deposits with fluids bringing calcium and aluminum to react with the serpentine along narrow fractures. The Fe, Ti and REE were possibly derived from the ser-

Figure 31. **Diagramatic representation of the sequence of crystallization in the veins of the Benitoite Gem mine.**



pentine along the fracture system. If similar solutions passed through fractures in the meta-basalt, Fe, Ti and REE could have formed silicates with barium. Since these Ba-silicates are restricted to meta-basaltic rocks, the Ba was probably derived from these rocks. Basalts commonly contain trace, but persistent, amounts of copper sulfides, which easily recrystallize in fracture systems.

The close association of djurleite and digenite with benitoite and neptunite indicates that all these minerals formed at about the same time and under the same conditions. Experimental work by Potter (1974) shows that djurleite is not stable at temperatures above 95°C. This would imply that all the minerals in the veins crystallized at temperatures below 95°C.

Coleman (1957) suggested that the natrolite may have been derived from a syenite intrusive emplaced less than a mile south of the Benitoite Gem mine. The syenite was intruded into the serpentine, and the outer margin contains veins and masses of natrolite. Natrolite is found in some veins cutting the serpentine in the vicinity of the syenite. However, natrolite is not found with benitoite in the other two localities to the west.

ACKNOWLEDGEMENTS

We acknowledge the generosity and hospitality of Elvis "Buzz" Gray and William Forrest during our several visits to the Benitoite Gem mine. They also supplied much of the information on earlier mining. We also appreciate Eugene and Sharon Cisneros taking us to visit their Mina Numero Uno.

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JONESITE

a new mineral from the Benitoite Gem Mine, San Benito County, California

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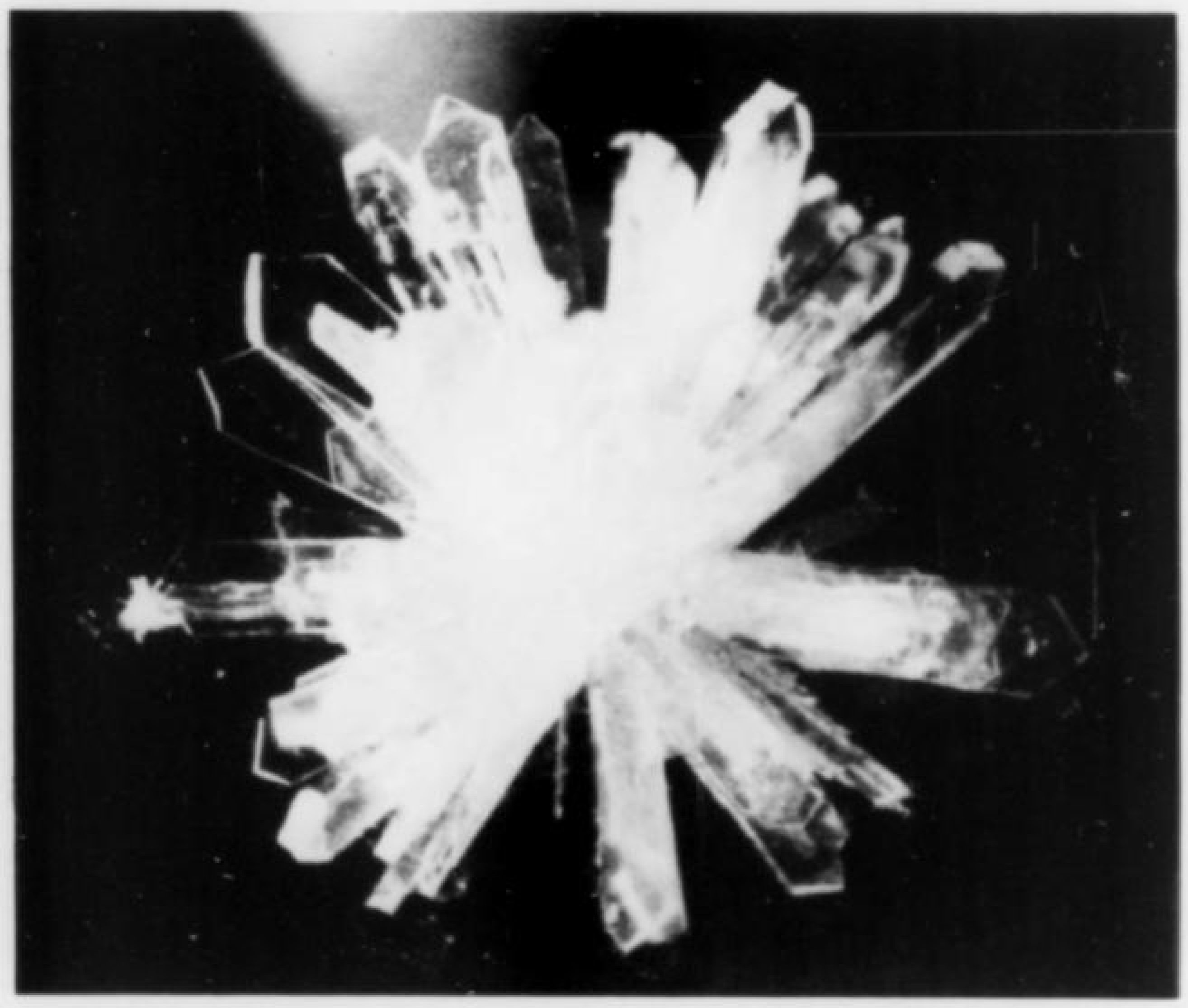
Figure 1. (above) **A view of the open cut at the Benitoite Gem mine, showing the recovery of the large block of veined greenstone containing jonesite (Spring, 1970). W.C. Forrest photo.**

Figure 2. (below) **A cluster of colorless jonesite crystals 3 mm across on neptunite. Note the dominant pinacoid and dome faces. R. Gill specimen and photo.**



JONESITE occurs in natrolite-filled veins at the Benitoite Gem mine, San Benito County, California, closely associated with neptunite and joaquinite, but not benitoite. A weighted average of 20 electron and ion microprobe analyses over several crystals yields the following composition: **SiO_2** 32.54, **TiO_2** 17.31, **B_2O_3** 0.008, **Al_2O_3** 5.52, **Fe_2O_3** 0.16, **MnO** 0.035, **MgO** 0.111, **CaO** 0.045, **SrO** 0.051, **BaO** 34.88, **Na_2O** 0.67, **K_2O** 2.70, **Nb_2O_5** 0.022, **H_2O** 5.9, **total** 99.952, giving a general formula **$(K,Na,Ba)_{1-2}Ba_4Ti_4Al_{1-2}Si_{10-11}O_{36}\cdot 6H_2O$**.

Jonesite crystals are pointed blades up to 1 mm long and occur most commonly in rosettes. The blades exhibit orthorhombic symmetry of the **class** ***m*2*m*** with the forms {**010**}, {**310**}, {**2$\bar{1}$0**}, and {**101**} most common, and the forms {302}, {403}, {313}, and {312} only on the largest crystals. Single crystal X-ray diffraction photographs indicate the **space group** ***B*22$_1$2**, and cell dimensions, refined from powder data, ***a*** = **13.730**(5)Å, ***b*** = **25.904**(5)Å, **and *c*** = **10.608**(3)Å; volume = 3773 Å^3; Z = 4.

The crystals are colorless, but fluoresce orange in shortwave ultraviolet light. Cleavage is parallel to (010); hardness is near 3-4. The measured **density** is **3.25**(1) g/cm^3; the calculated density for average cell contents is 3.239 g/cm^3. Jonesite is **biaxial** (+), α = **1.641**, β = **1.660**, γ = **1.682**, and **2V** = **76°-78°**. The optic plane is parallel to (100) with X parallel to *b* and Z parallel to *c*.

The strongest lines of the X-ray powder pattern (d value in Å, relative intensity, indices) are 12.95 **100** *(020)*; 3.031 **45** *(440)*; 3.008 **18** *(262)*; 2.652 **30** *(004)*; 2.596 **17** *(024)*; 2.228 **20** *(2·11·0)*; 2.158 **17** *(0·12·0)*; 2.073 **18** *(622)*.

The name honors Francis T. Jones of Berkeley, California.

INTRODUCTION

For the past 70 years the Benitoite Gem mine in San Benito County, California, has produced thousands of specimens of three unusual and rare minerals—benitoite, neptunite, and joaquinite. In 1907 Louderback published a brief description of benitoite as a new gem mineral and mentioned another mineral which proved to be identical with the neptunite from Greenland, described only a decade earlier. Because of the pleasing blue color and unusual symmetry, there quickly followed a flurry of papers describing the crystallography of benitoite, as well as neptunite. In 1909 a complete description of the occurrence was published by Louderback. By that time the deposit was actively being exploited by the Dallas Mining Company. In his report Louderback (1909) provided a careful and complete description of the deposit and its geologic relations, as well as the mineralogy. In this later report he also described another new mineral, joaquinite, with such a complicated composition that only recently has it been fully determined (Laird and Albee, 1972).

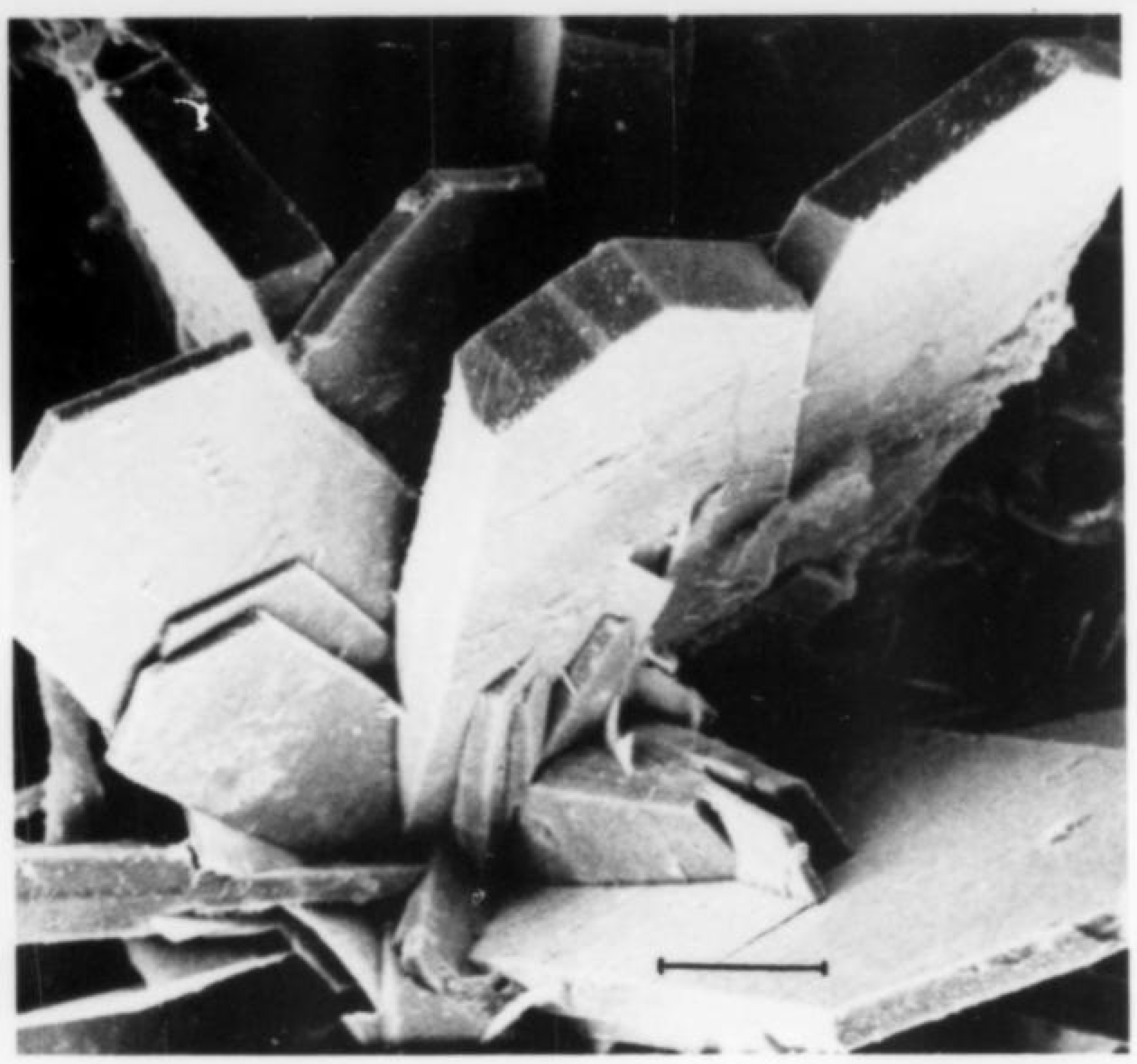


Figure 3. (left) **A scanning electron micrograph of a small jonesite cluster. Note that these small crystals are terminated with the simple form {101}. Length of the bar is 0.1 mm.**

Benitoite, neptunite, and joaquinite occur in natrolite-filled veins that branch and anastomose in blue-schist composed chiefly of actinolite and crossite. The benitoite, neptunite, and joaquinite have grown on the walls of fractures and cavities of brecciated greenstone. Most of the open spaces were later filled with natrolite, covering the earlier formed minerals. Specimens were prepared by treatment with hydrochloric acid, which decomposes the natrolite, leaving a silica gel. The reaction is stopped and the gel removed by immersion in a strong alkaline bath.

In 1957 Francis T. Jones found in the acid baths single blades or small clusters of crystals of a mineral not previously recognized from the mine. The amount of material was sufficient to determine that it was a new mineral, but insufficient to fully characterize it for description (Jones, 1971). The renewed mining activity by W. C. Forrest and Elvis Gray uncovered a huge block of the veined blue-schist in 1970 (see Fig. 1), from which many superb specimens of neptunite have been recovered. On a few of these specimens numerous rosettes of the new mineral were exposed by the acid treatment. This paper describes this new mineral, for which the name jonesite* is proposed in recognition of the discovery and early work by Francis T. Jones of Berkeley, California.

Table 1. Chemical composition of jonesite

weighted average of 18 microprobe analyses		**cell contents**	(average)	(range)
SiO_2	32.54	Si	9.97	10.10 - 9.90
TiO_2	17.31	Al	1.99	1.86 - 2.10
B_2O_3*	0.008			
Al_2O_3	5.52	Ti	3.99	3.90 - 4.05
Fe_2O_3	0.16	Fe	0.04	—
MnO*	0.035	Mn	0.01	—
MgO*	0.111	Mg	0.05	—
CaO*	0.045	Ca	0.01	—
SrO*	0.051	Sr	0.01	—
BaO	34.88	Ba	4.19	4.15 - 4.41
Na_2O	0.67	Na	0.40	0.30 - 0.47
K_2O	2.70	K	1.06	0.70 - 1.10
Nb_2O_5*	0.022	H_2O	6.0	
H_2O**	5.9	Calculated density for average cell contents: 3.239		
total	99.952			

General formula:
$(K,Na,Ba)_{1-2}Ba_4Ti_4Al_{1-2}Si_{10-11}O_{36}\cdot 6H_2O$

Z = 4

*Elements determined by ion microprobe mass analyzer, others determined by electron microprobe

**Water determined by ion microprobe, also by difference in electron microprobe data.

DESCRIPTION

Chemical Composition

The determination of the composition of jonesite presented the most difficulty in the characterization of the mineral. It was evident in the early attempts at electron microprobe analysis that the composition was somewhat variable, even within a single crystal. Because the total available supply of the mineral was and remains small, analysis was only to be accomplished by microprobe methods. However, bubbling from the sample under the electron beam indicated that the sample was hydrated; water analyses cannot be made with an electron microprobe. For this reason, and because of a desire to determine all the major and minor elements in the mineral, complete mass scans (looking for every element) were made with the ion microprobe.

Several crystals were embedded in epoxy, ground to expose the centers, and coated with carbon. These crystals were analyzed at about ten spots. Ten additional analyses were obtained from the surface of a large single crystal. The electron microprobe analyses were carried out under the following conditions: accelerating voltage 15kV for all elements; sample current 8 nanoamps; spot size 20 micrometres; standards, benitoite for Ba, Ti, and Si; K-feldspar for K; and albite for Na. Data were reduced and interelement corrections applied with a modified version of EMPADR7 (Rucklidge and Gasparrini, 1969, Department of Geology, University of Toronto). The ion microprobe analyses were carried out with a negatively charged primary beam of monatomic oxygen ($^{16}O^-$) at 17 kV. The spot size was approximately 20 micrometres and a sample current of 6 nanoamps. The hydrogen content was estimated from the working curves of Hinthorne and Anderson (1975), and the other element data were quantitatively reduced, using sensitivity factors derived from a theoretical ionization model (Anderson and Hinthorne, 1973).

In order to determine whether the hydrogen in the mineral was bonded as hydroxyl or water molecules, an infrared absorption spectrum was obtained by George R. Rossman at California Institute of Technology. The absorption spectrum was obtained from a pellet of the powder of several crystals (180 micrograms) in KBr. The strong absorption band at 1635 cm^{-1} indicates that water molecules are by far dominant in the mineral.

The resulting analyses are given in Table 1. From calculations, using the measured density, the unit cell volume (Table 2), and the average composition, a general formula was obtained (Table 1). The composition is that of a hydrated form of $BaTiSi_3O_9$, **benitoite**, in which Al has replaced some of the Si, and the resulting charge is balanced by K, Na, and extra Ba. The variation in K, Al, Ba, and Si from spot to spot in the crystals is probably a result of the coupled substitution K + Si = Ba + Al.

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*The description and name have been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association.

Table 2

X-ray powder diffraction data for jonesite. Least squares refinement of cell dimensions gives $a = 13.730(5)$ Å, $b = 25.904(5)$ Å, $c = 10.608(3)$ Å, and $V = 3773(1.4)$ Å^3. Powder data were standardized with Si ($a = 5.4309$ Å) and taken with CuK ($\lambda = 1.5418$ A). The pattern was indexed for the space group $B22_12$, but *hkl*'s with *h* or *l* odd were also excluded. Intensities were derived from measurement of peak heights on a diffractometer strip-chart recording.

hkl	d_{calc}	d_{obs}	I/I_1
020	12.95	12.95	100
040	6.47	6.46	10
012	5.20	5.19	3
032	4.52	4.51	3
202	4.20	4.19	2
250	4.14	4.13	2
222	3.99	3.99	10
052	3.71	3.70	15
242	3.52	3.51	13
400	3.43	3.43	5
420	3.32	3.32	2
440	3.033	3.031	45
262	3.009	3.008	18
412	2.864	2.868	8
422	2.813	2.818	2
432	2.733	2.737	10
460	2.687	2.690	3
004	2.652	2.652	30
024	2.598	2.596	17
282	2.564	2.562	3
092	2.530	2.527	5
214	2.463	2.465	3
044	2.454	2.452	3
472	2.274	2.273	6
064	2.260	2.259	7
2.11.0	2.228	2.228	20
0.12.0	2.159	2.158	17
404	2.099	2.101	8
622	2.074	2.073	18
2.11.2	2.054	2.054	5
642	1.999		
444	1.996	1.998	10
2.13.0	1.914	1.914	8
464	1.887	1.888	2
294	1.876	1.875	3
0.14.0	1.850	1.850	3
474	1.825	1.826	2
4.11.2	1.823	1.822	2
690	1.791		
2.10.4	1.789	1.791	2
016	1.764	1.764	2
484	1.761		
0.11.4	1.761	1.760	2
624	1.717	1.719	2
810	1.712		
206	1.712	1.713	2
2.11.4	1.706	1.706	10
634	1.698	1.699	9
494	1.696		
2.14.2	1.693	1.695	5
2.15.0	1.675	1.675	3
246	1.655	1.656	4
0.15.2	1.642	1.642	12
860	1.552	1.551	4
0.16.2	1.548	1.549	4

plus at least 10 weak
lines to 1.14

Crystal Geometry

Cell dimensions were determined by means of *hOl* and *Okl* precession photographs, a *c*-axis rotation photograph, and an *hk*O Weissenberg photograph, allowing two or three independent measurements on each cell edge. First, second, and third level Weissenberg photographs (*hk*1, *hk*2, and *hk*3) were taken to check for proper indexing and for systematic extinctions. The cell dimensions were refined from the X-ray powder diffraction pattern (see Table 2), standardized with Si metal ($a = 5.4309$ A), using CuKα radiation ($\lambda = 1.5418$ A).

The diffraction symmetry is *mmm* indicating orthorhombic symmetry. Indexing of the Weissenberg photographs is limited to $h+l = 2n$ in *hk*l reflections and $k = 2n$ for O*k*O, which lead to only one space group, $B22_12$. Not only are all *hkl*'s weak for *l* odd, as seen on the *c*-axis rotation photograph, but all *hkl*'s for *h* odd are also very weak. These observations indicate a smaller pseudocell, whose axes are $a = 6.88$ Å, $b = 25.95$ Å, and $c = 5.31$ Å. Reindexing leads to the pseudospace group for the cell $I\frac{2}{m}\frac{2}{m}\frac{2}{m}$.

Crystal Morphology

Jonesite crystals are slender blades terminated with dome faces. These blades most commonly form rosettes, composed of several tens of crystals (see Fig. 2 and 3). The rosettes may be as large as 3 mm across or as small as 0.2 mm.

Individual jonesite crystals commonly have six faces forming a prism (see Fig. 4). The relatively large crystal, shown in Figure 4, which was coated with gold for the SEM photograph, was suitable for optical goniometric measurements. The faces identified are $\{010\}$ and $\{0\bar{1}0\}$, the largest pinacoid faces with $\{310\}$, $\{\bar{3}10\}$, $\{2\bar{1}0\}$, and $\{\bar{2}\bar{1}0\}$ forming the prism (see Fig. 5). The dome faces terminating the crystal are simple—commonly $\{\bar{1}01\}$ and $\{101\}$—if the crystal is small. However, complex, irregular surfaces develop on the larger crystals (compare Fig. 2 and 4). Goniometric measurements on the Figure 4 crystal indicate the crystal class *m*2*m*. Moreover, the goniometric measurements, as well as X-ray photographs clearly disprove the suggestion that the forms, illustrated in Figure 4, have resulted from twinning on the (010) plane.

Physical Properties

All the observed crystals are colorless. Jonesite fluoresces dull orange in shortwave ultraviolet light, but is nonfluorescent under the longer wavelengths. The density is 3.25 (± 0.01) g/cm³, measured by a sink-float

Figure 4. (left) **A scanning electron micrograph of a single, large jonesite crystal. Faces other than the $\{010\}$ pinacoid are $\{310\}$ and $\{2\bar{1}0\}$. X-ray diffraction and goniometric measurements prove that the re-entrant faces are not a result of twinning, but from the rapid growth of the $\{010\}$ faces. Length of the bar is 0.1 mm.**

method in acetone diluted di-iodomethane. The crystals have a hardness near 3 to 4.

Crystals break irregularly across the blades, but cleave parallel to the (010) plane.

Optical Properties

Jonesite is biaxial (+), $\alpha = 1.641$, $\beta = 1.660$, $\gamma = 1.682$ (all ± 0.001), and $2V = 76°$ to $78°$. The optic plane is parallel to (100) with X parallel to *b* and Z parallel to *c* (see Fig. 5).

Type Specimen

The type specimen is preserved in the mineral collection in the Department of Geological Sciences at the University of California, Santa Barbara, as specimen USCB 7325. A similar specimen is in the collection of the American Museum of Natural History.

ORIGIN

Jonesite, so far as it is presently known, occurred only in a few of the veins at the Benitoite Gem mine. It has been found closely associated with neptunite and joaquinite, most commonly having grown near or on those earlier formed crystals. Jonesite has not been found in close proximity to benitoite.

These observations lead to the conclusion that the jonesite grew from the same fluids from which the other minerals crystallized. Jonesite does not appear to have grown at the expense of benitoite, but rather in its place, possibly where the fluids were too aluminous for benitoite. Jonesite will most likely be found in the rare type of environment where benitoite can also grow at low temperatures.

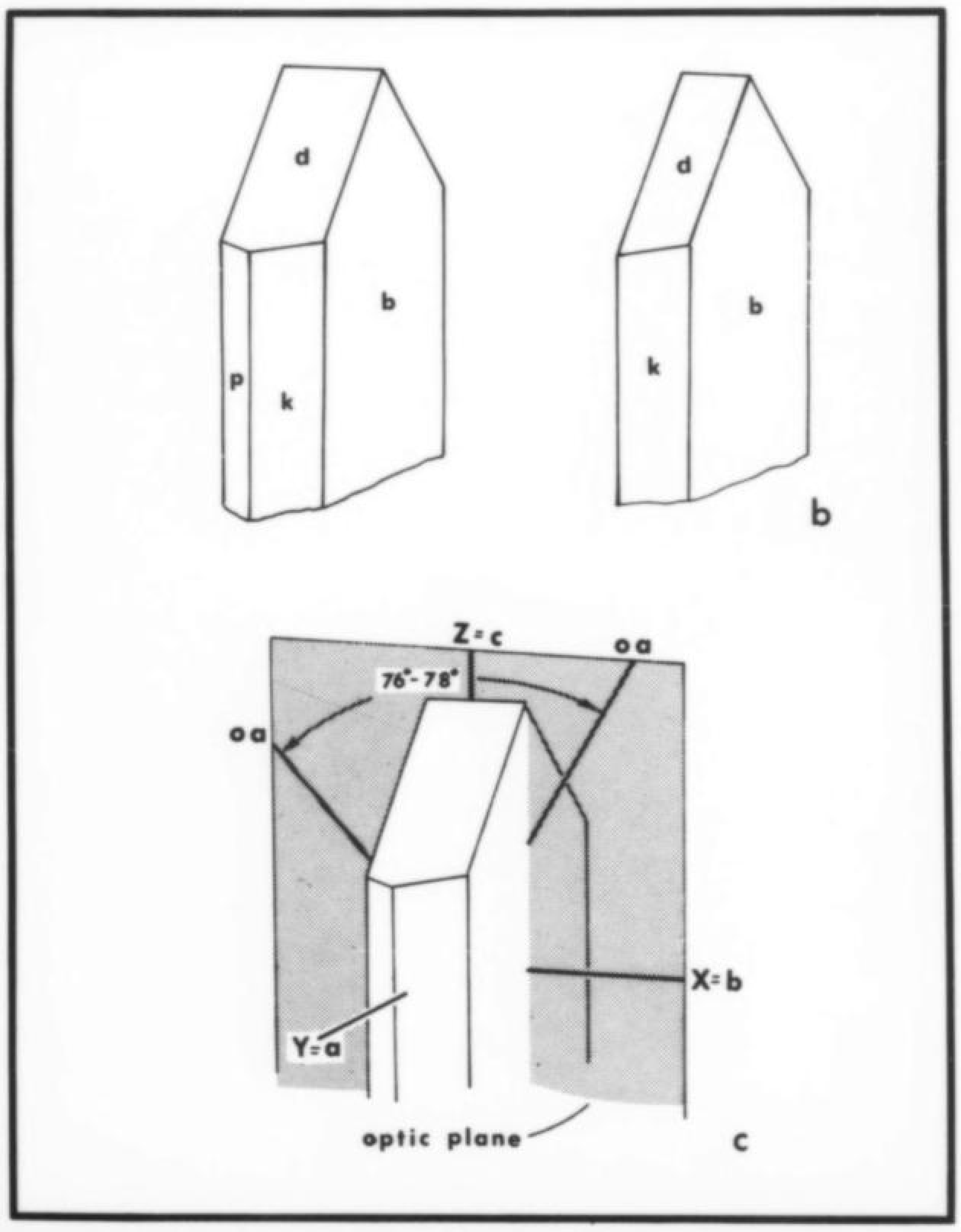

Figure 5. **Crystal forms and optical properties of jonesite crystals. (a and b) The crystals have the forms *b* {010}, *k* {310}, *p* $\{2\bar{1}0\}$, and *d* {101}, and belong to the crystal class *m2m*. (c) The optic orientation of jonesite.**

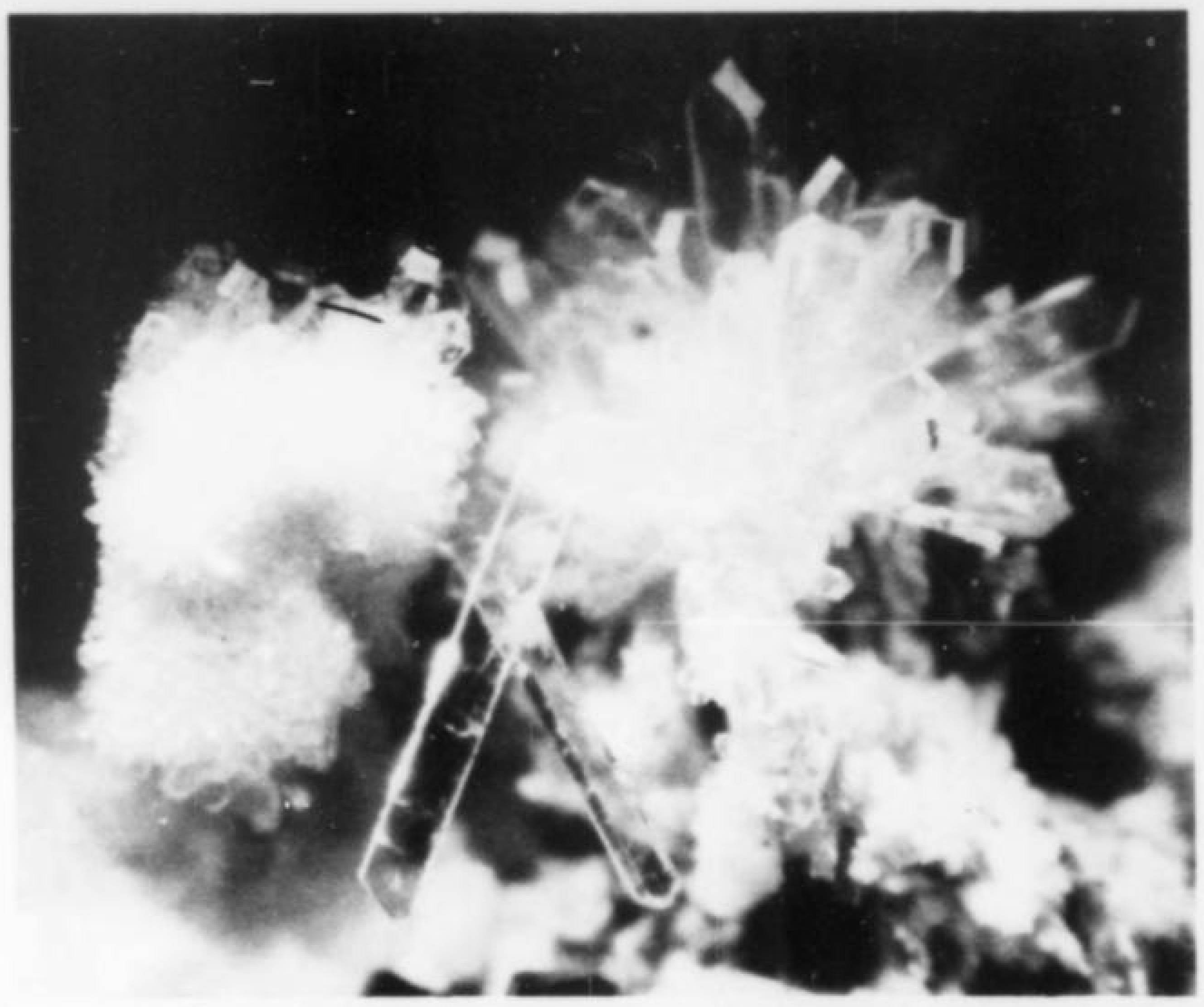

Figure 6. **Colorless jonesite clusters and single crystals. The longest jonesite crystal is less than ½ mm in length. R. Gill specimen and photo.**

ACKNOWLEDGEMENTS

We are particularly indebted to W. L. Forrest, Elvis "Buzz" Gray, and C. D. Woodhouse for making the excellent specimen material available to us. Thanks go also to Robert Gill for the photographs and for access to other specimens from the Benitoite Gem mine, and we appreciate Eugene and Sharon Cisneros taking us to visit their Mina Numero Uno.

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ARTINITE

from San Benito County

CALIFORNIA

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ABSTRACT

A recent discovery of artinite in San Benito County, California, has produced some of the finest specimens known in the world today. This paper describes the geology of the locale and some of the exceptional specimens obtained. Techniques of Scanning Electron Microscopy and Infrared Spectroscopy have been employed to characterize the material morphologically and structurally. Hydromagnesite "puff balls" and calcite crystals have been found associated with the artinite, as well as orange crystalline to earthy pyroaurite, and dypingite (Erd, 1976).

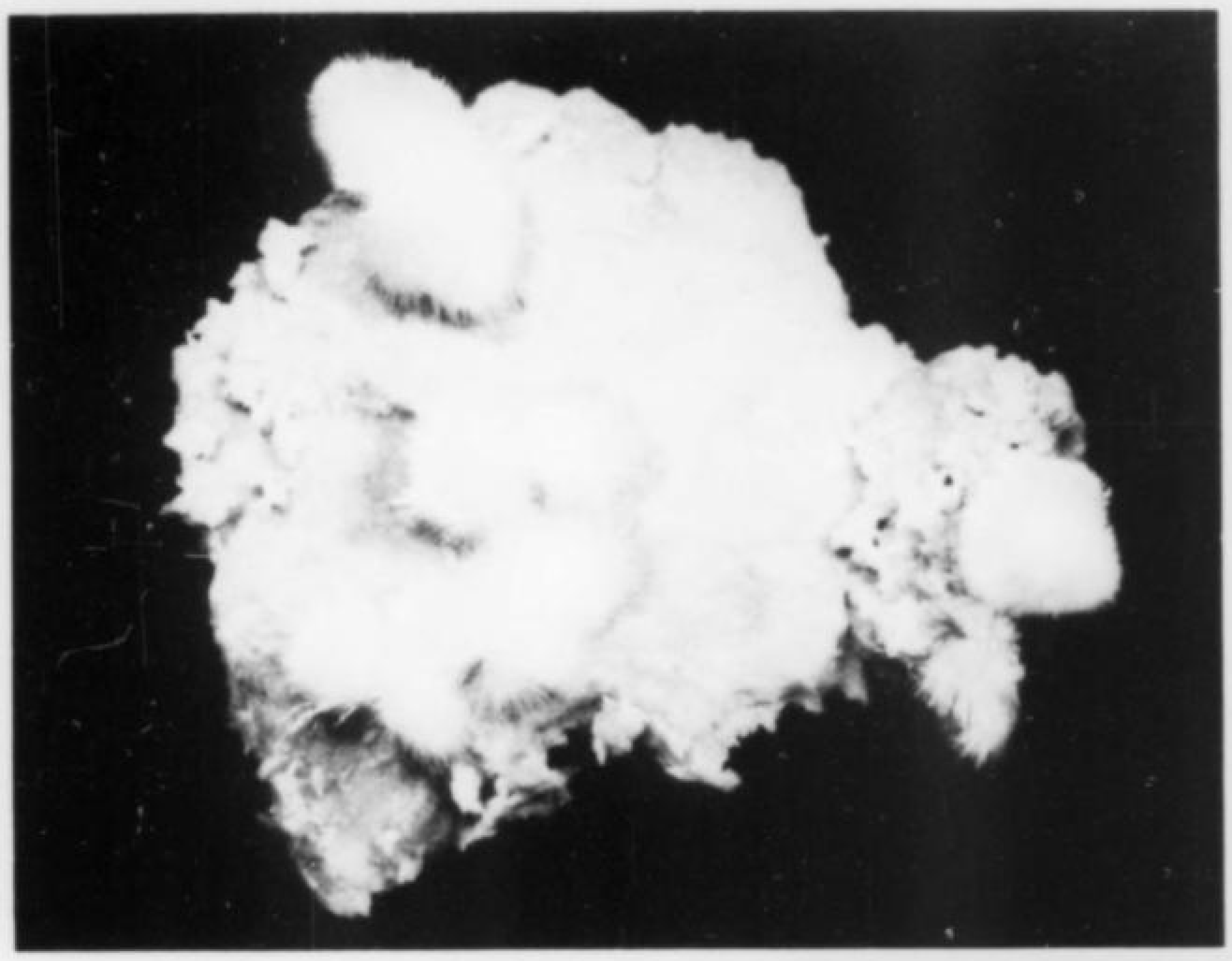
Figure 1. (below) **General view of the main collecting area. S. Cisneros photo.**

Figure 2. (right) **Detailed view of the main collecting area. S. Cisneros photo.**

Artinite, a pure white basic carbonate of magnesium, $\mathbf{Mg_2(CO_3)(OH)_2 \cdot 3H_2O}$, was first found at Val Malenco, Italy, and was described by Brugnatelli in 1902. He named the new mineral after E. Artini, professor of mineralogy at Milan Polytechnic and director of the Natural History Museum of Milan (Bedogné and Pagano, 1972). A low-temperature hydrothermal mineral, artinite is commonly found as crusts of acicular crystals, cross-fiber veinlets, botryoidal masses of silky fibers, and as spherical aggregates of radiating fibers coating fracture surfaces in serpentinized ultrabasic rocks. It is commonly associated with hydromagnesite, brucite, aragonite, calcite, dolomite, magnesite, pyroaurite, and chrysotile.

A recent find of artinite by one of the authors (SLC) in southern San Benito County, California, has produced some of the finest specimens known in the world today. The deposit is situated in the New Idria district in the rugged Diablo Range about 140 miles southeast of San Francisco. The geology of the district has been described by Eckel and Myers (1946) and by Coleman (1957) and only the pertinent points are mentioned here. Artinite occurs within the New Idria serpentinite, a large oval body which forms the core of a breached anticline, trending N. 70° W., flanked by Jurassic and Cretaceous sediments. The dome is marked on the northeast flank by overturned beds and by high-angle faulting along the contacts of the serpentinite body with the enclosing sediments. The mineralogy and origin of the asbestos in the serpentinite have been described by Mumpton and Thomson (1975). Scattered throughout the area of sheared and weathered serpentinite are outcrops of silica-carbonate rock and residual "boulders" of hard, dark green to brown serpentinite masses. The greater part of the serpentinite is very strongly sheared and resembles talc in appearance and feel. An old talc prospect in one such zone, situated about 1.5 miles west of San Benito Mountain, is the site of this find of exceptional artinite specimens.

Although artinite has been found for a number of years at various localities within the serpentinite dome area of San Benito



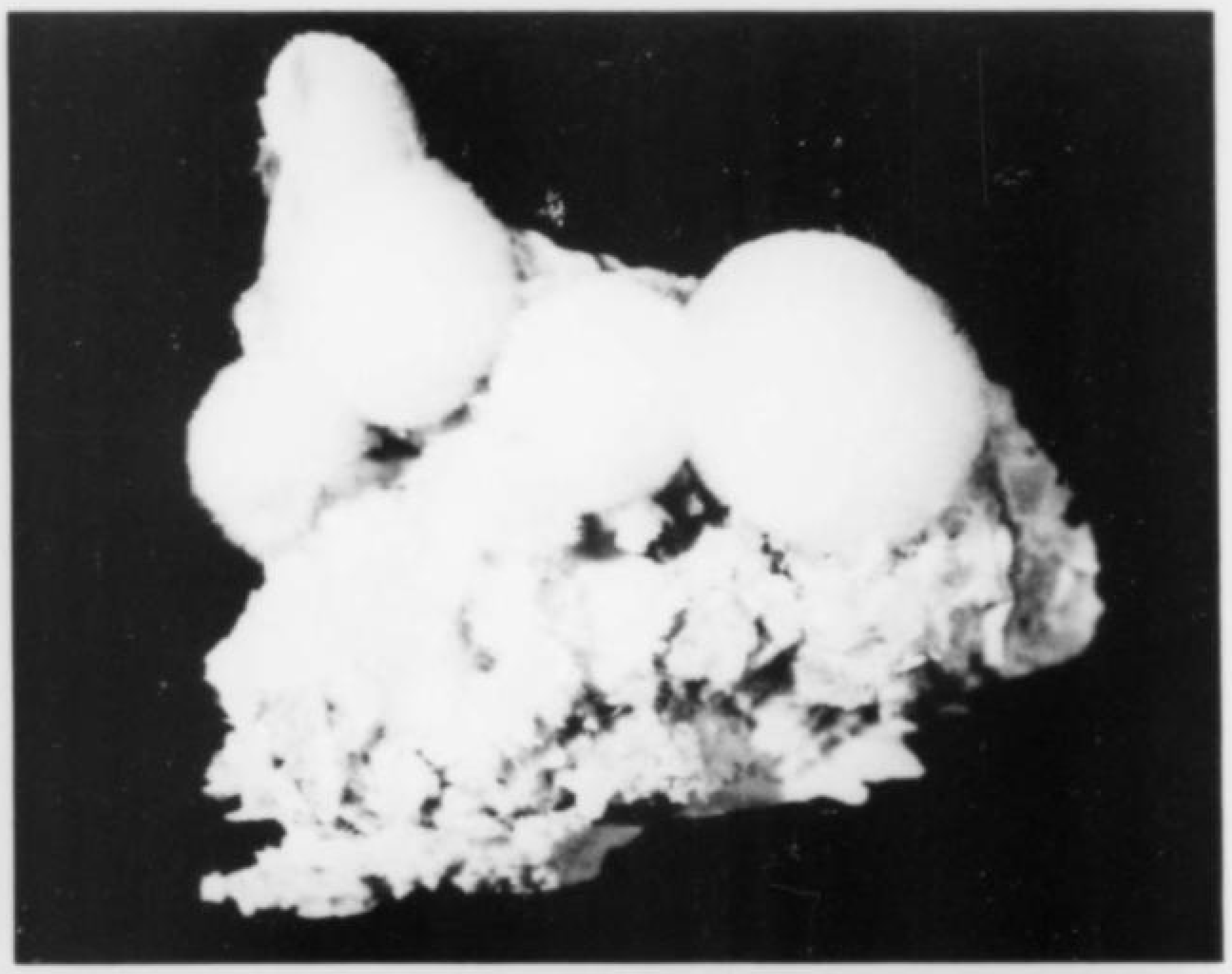


Figure 3. (above) **Artinite tufts on serpentine matrix. A typical specimen. D. L. Oswald photo.**

Figure 4. (above right) **An exceptionally fine artinite specimen. The spherical formation on the right of this specimen is 25 mm in diameter. D. L. Oswald photo.**

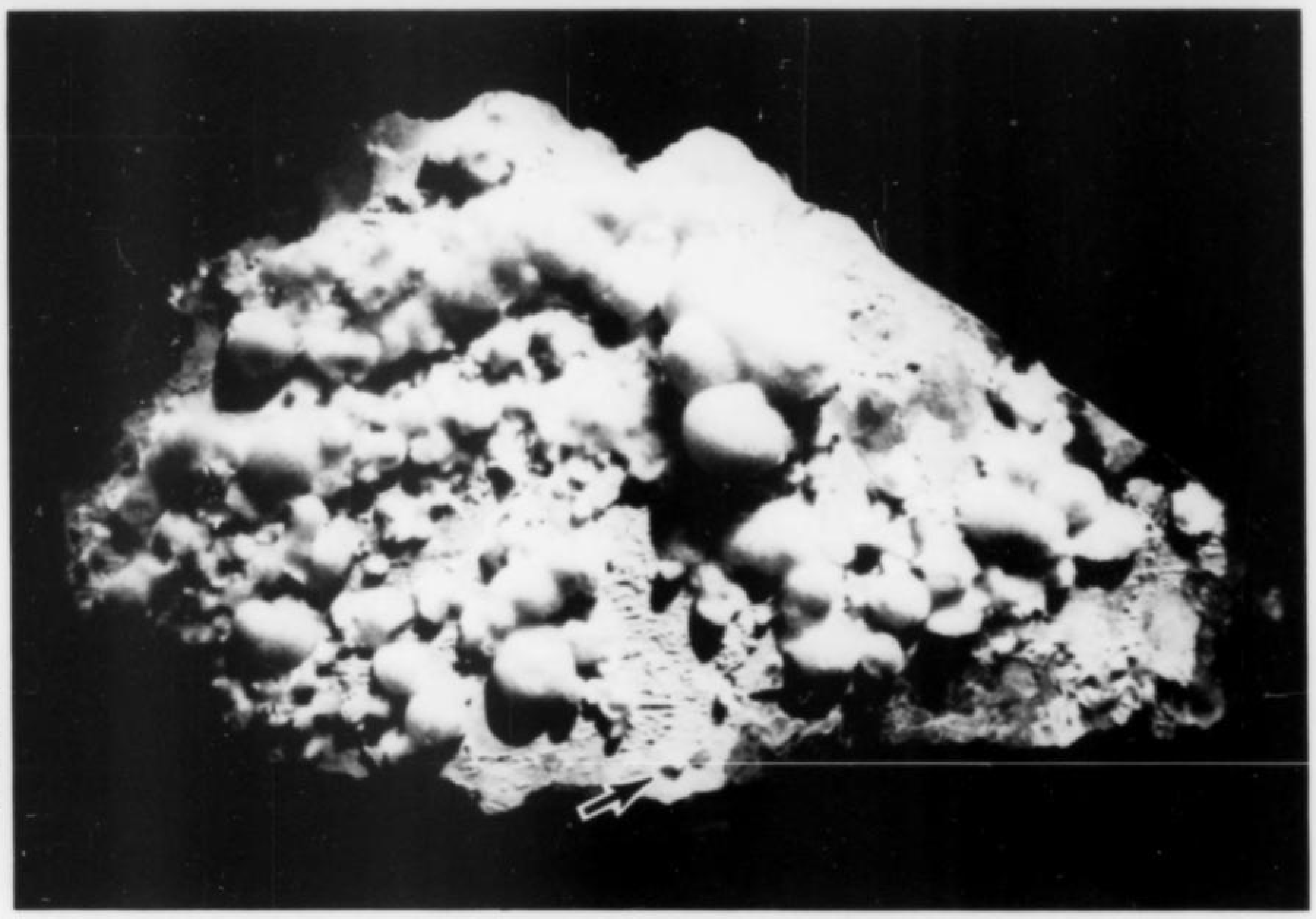


Figure 5. (right) **A museum quality artinite specimen, overall size is 17.5 X 37.5 cm. Note the small "bow-tie" formation on the lower edge near the center. D. L. Oswald photo. CMNH 18129.**

Figure 6. (left) **A photomicrograph of the artinite "bow-tie" formation noted in Figure 5. The formation is 12 mm in length. D. L. Oswald photo. CMNH 18129.**

County, no large quantity of exceptional specimens had been collected. Until the new find at this particular locale, which is shown in Figures 1 and 2, collecting in this area was only poor to mediocre. As a result of natural weathering of the serpentinite in the upper area of the pit, some large boulders gradually became exposed. It was in the cavities between these large boulders that artinite formed. In general the seams were thin and pinched out in places. However, where the seams opened up, artinite spheres were found lining the resulting cavities. One of these pockets attained dimensions of 1.2 m tall by 1.5 m deep by 0.3 m wide. The thin layer of serpentine lining the cavities made it easy to pry out flat plates completely covered with spheres composed of individual artinite crystals. Thus the exceptionally delicate, snow white artinite crystals were collected for the first time in rather large quantities. The relatively soft serpentine lining the cavities made it possible to remove a high percentage of the artinite as beautiful, undamaged specimens.

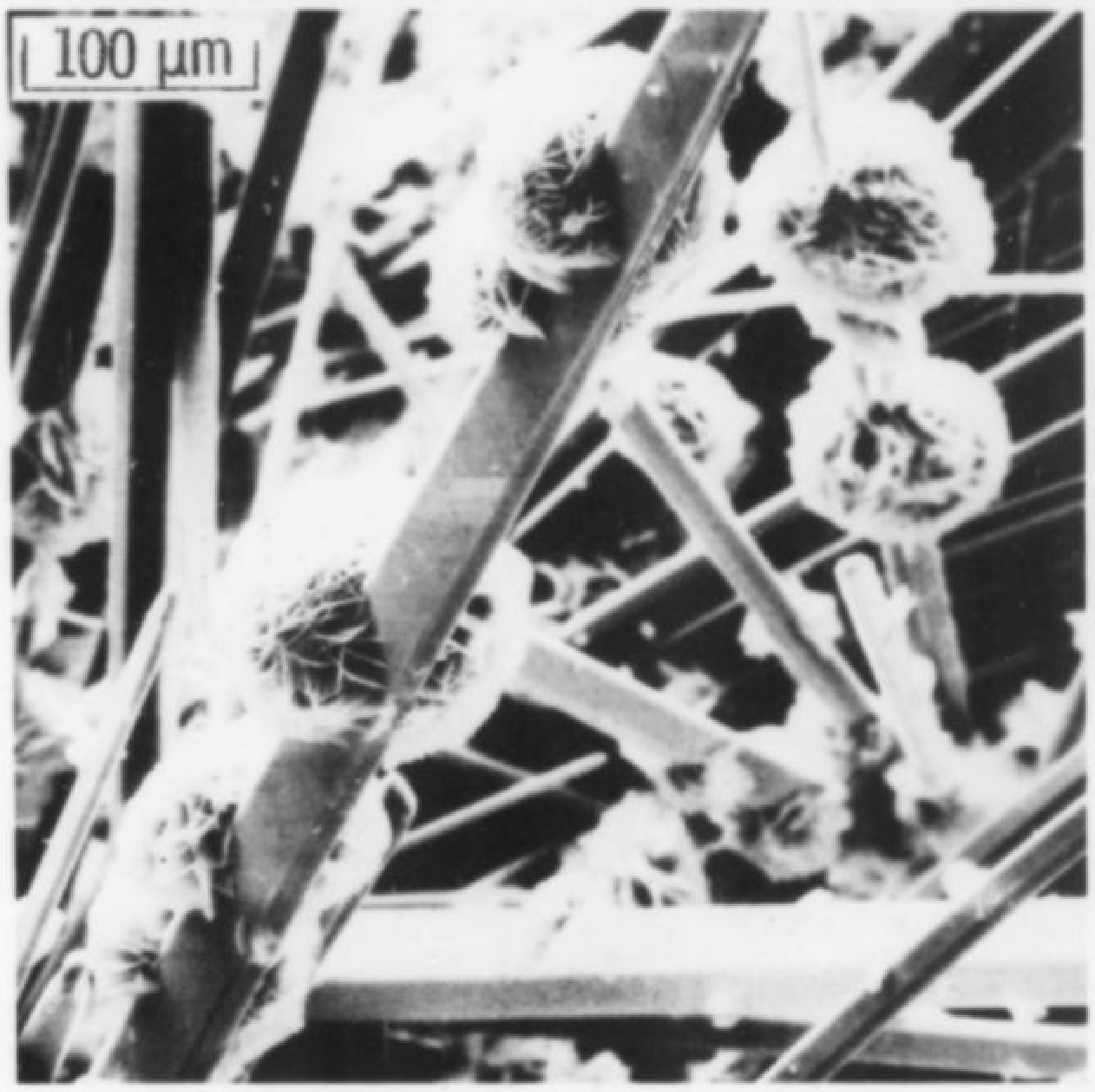
A number of exceptionally fine artinite specimens have been removed from this locale since the new find was made. Figure 3 shows a typical specimen with individual tufts greater than 25 mm in length; the overall size of the specimen is 50 by 75 mm. An example of exceptionally fine crystalline formations is shown in Figure 4; the crystalline spherical formation on the right of this specimen is 25 mm in diameter. A museum quality specimen is shown in Figure 5; the physical dimensions of this specimen are 17.5 by 37.5 cm, and it is now a part of the mineral collection of the Carnegie Museum of Natural History, Pittsburgh, Pennsylvania. Upon close examination of this specimen a small "bow-tie" crystal group measuring 12 mm in length may be noted on the lower edge near the direct center. A photomicrograph of this group is shown in Figure 6. Other large specimens have been placed in the collections of the Smithsonian Institution, Los Angeles County Museum of Natural History, the University of Copenhagen, and the Musee de Mineralogie de L'Ecole des Mines in Paris.

Detailed microscopic observations of selected artinite specimens were made by scanning electron microscopy. The specimens were mounted on standard specimen stubs with electrically conducting silver cement, and were carbon coated to render them electrically conductive. A Cambridge Stereoscan SEM was employed for this study. The details of the SEM technique have been previously described in this journal by Wilson (1972).

As shown in Figure 7, the artinite needles were found to be closely associated with another crystalline formation. These delicate microcrystalline "puff-balls" are shown in greater detail in Figure 8, attached directly to the artinite material and, in some instances, pierced by the crystalline needles. The morphological features of a "puff-ball" formation are shown in Figure 9; this material was later identified by infrared spectroscopy as hydromagnesite.

Infrared spectroscopy analyses were made of both the artinite crystals and hydromagnesite "puff-balls"; a Beckman IR-12 grating spectrometer was employed. The standard KBr pellet technique was utilized to disperse the samples in an infrared transparent medium for subsequent study. The frequency range covered in these measurements was 200 to 4000 cm^{-1}. Figure 10 details the infrared spectrum of both materials and confirms the artinite and hydromagnesite structures; these spectra agree with published literature (by White, 1971).

Figure 7. **An SEM micrograph of the artinite needles and associated hydromagnesite "puff-balls." R. Witkowski photo.**



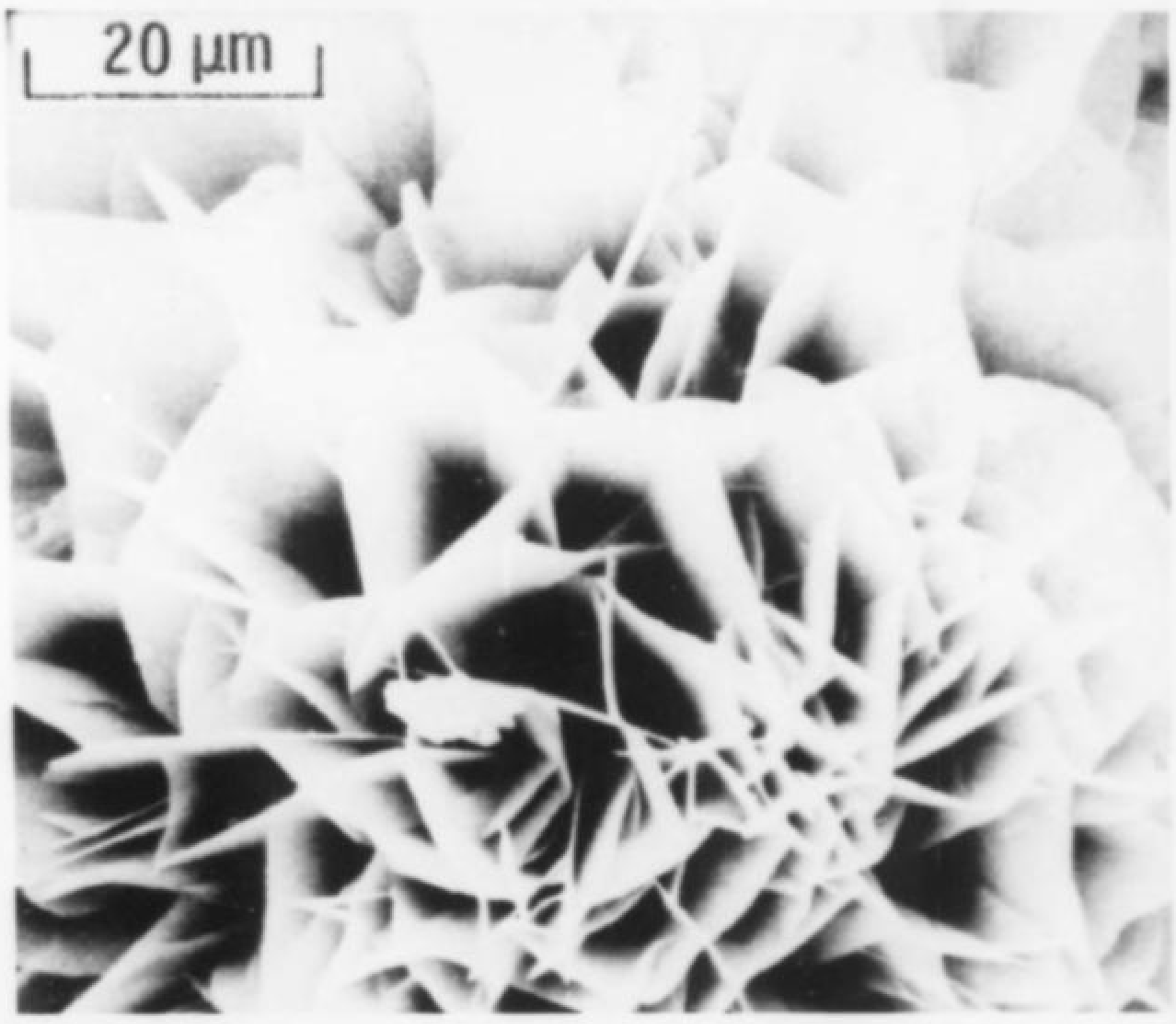


Figure 8. (center right) **A detailed SEM view of the artinite crystals and associated hydromagnesite growths. R. Witkowski photo.**

Figure 9. (bottom right) **An SEM micrograph detailing the morphology of the hydromagnesite "puff-balls." R. Witkowski photo.**

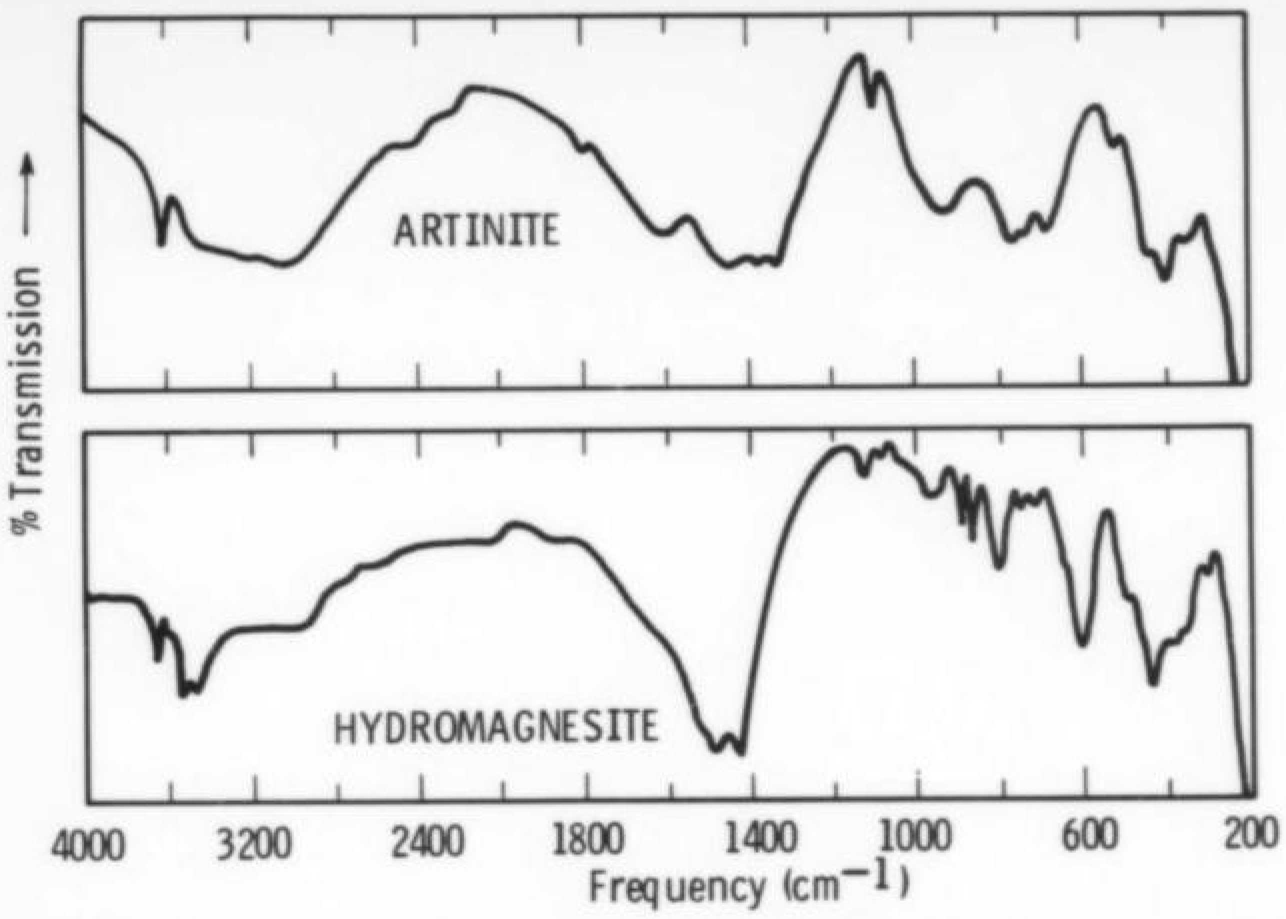


Figure 10. **Infrared spectra obtained for both the artinite needles and hydromagnesite "puff-balls." R. Witkowski.**

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FAMOUS MINERAL LOCALITIES:

The Himalaya Dike System

MESA GRANDE DISTRICT, SAN DIEGO COUNTY, CALIFORNIA

by Eugene E. Foord, U.S. Geological Survey, Denver Federal Center, Denver, Colorado 80225

The Himalaya pegmatite-aplite dike system of the Mesa Grande District, in the upland country southwest of Lake Henshaw in north-central San Diego County, California (Fig. 1) is world famous for its production of gem and specimen-quality tourmaline and numerous rare mineral species. It still ranks as North America's largest producer of gem tourmaline.

LOCATION MAP of the major pegmatite districts in San Diego County.

INTRODUCTION

The Himalaya dike system is composed of two pegmatite-aplite dikes, ranging in combined thickness from less than 19 inches to nearly 6 feet, accompanied by several thin branch stringers. These have been exploited by the Himalaya and San Diego mines. The dikes are sub-parallel and lie 13 to 35 feet apart in the vicinity of the Himalaya mine, but on the San Diego mine property they converge and are juxtaposed for a distance of more than 50 feet. They trend approximately N20E, dip 30 to 35 degrees toward the west, and outcrop for a distance of about a mile along the east-facing slope of Gem Hill. The host rock, a norite member of the Southern California batholith, has been hydrothermally altered adjacent to the borders of the dikes.

HISTORY

An excellent general history of much of the early pegmatite mining activity in San Diego County has been given by Kunz (1905) and more recently by Rynerson (1967) and Sinkankas (1976). No detailed description of the mineralogy and geology

Figure 2. (above) **Tourmaline (elbaite) on quartz from the Himalaya mine. Notice the large doubly terminated crystal at lower right. The crystal on the left is 12.5 cm tall. Trelawney collection, now part of the Smithsonian collection; NMNH# 137508. Photo by Wendell Wilson.**

Figure 4. (right) **Tourmaline (elbaite), doubly terminated and color-zoned. The crystal is 7.7 cm long, and is in the Smithsonian collection; NMNH# 118169. Photo by Wendell Wilson.**

Figure 5. (right) **Multi-colored tourmaline (elbaite) with quartz, albite and lepidolite, from the Himalaya mine. The largest crystal measures 8 cm tall; the specimen is in the collection of the Los Angeles County Museum of Natural History. Photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

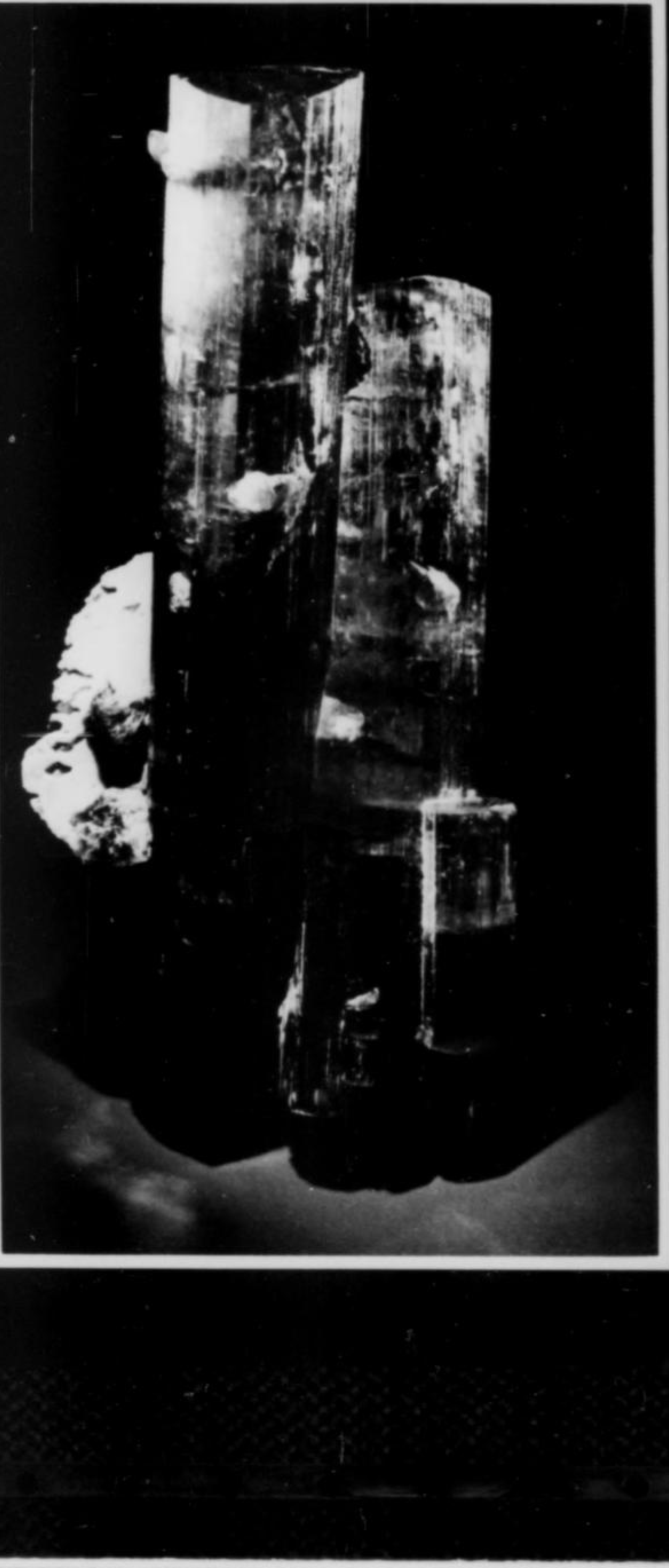
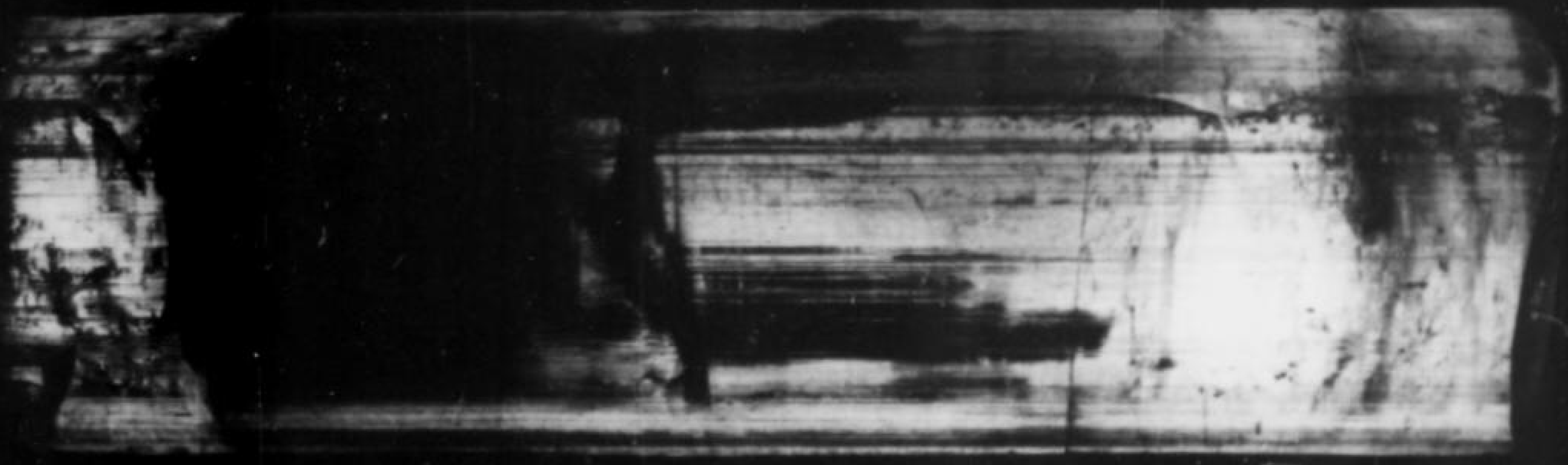
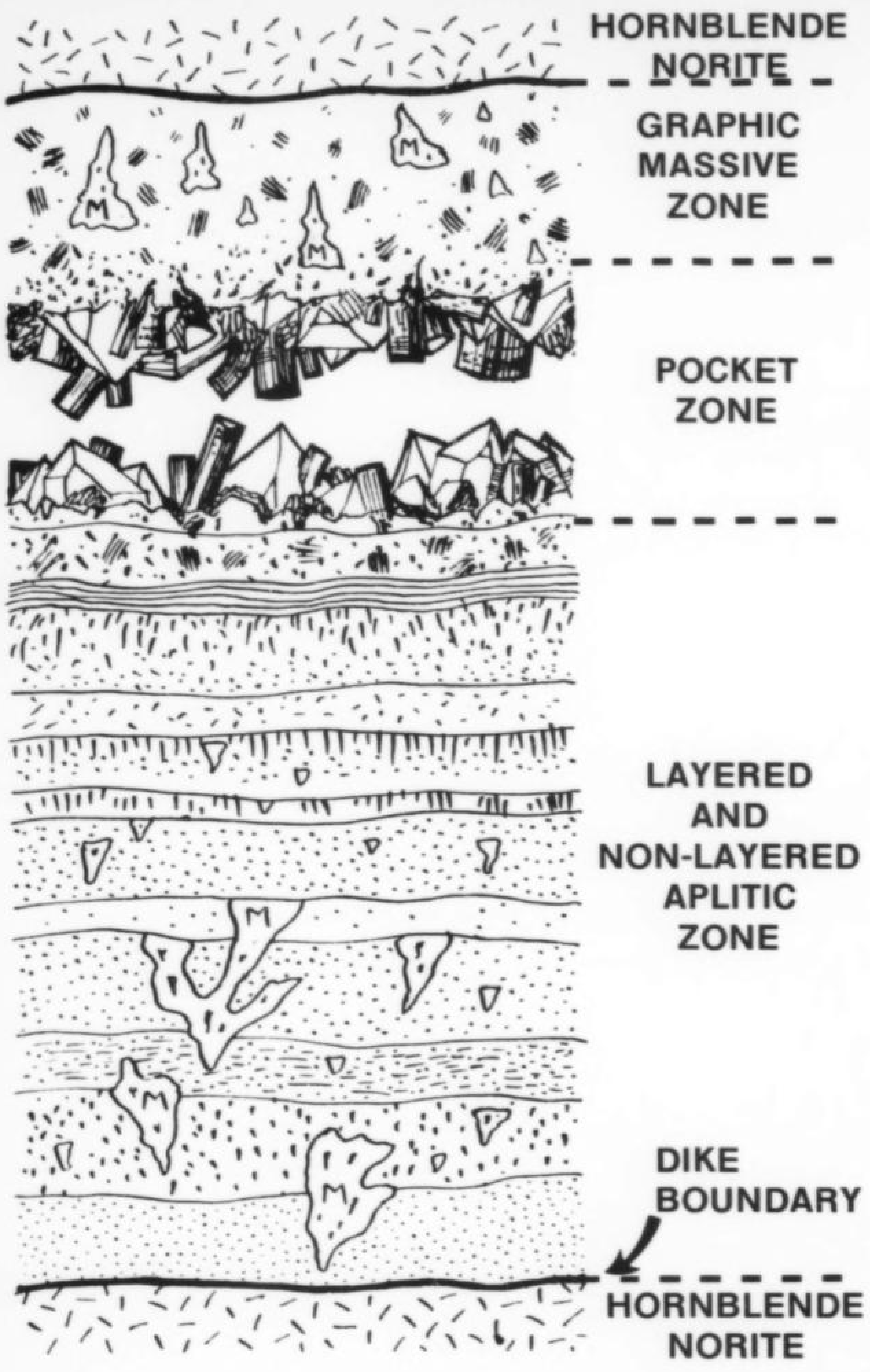


Figure 3. (right) **Tourmaline (elbaite), with a small piece of feldspar matrix, from the Himalaya mine. All three tourmaline crystals are doubly terminated; the longest crystal measures 9.4 cm. Trelawney collection, now part of the Smithsonian collection; NMNH# 137505. Photo by Wendell Wilson.**





Scale: 1 cm on the figure equals about 8 cm. M = microcline

***Figure 6.* An idealized section through the Lower Dike, as exposed within the San Diego tourmaline mine, showing all zones developed.**

of the Himalaya dike system has been previously published, although it has been studied by W. T. Schaller and by R. H. Jahns and J. B. Hanley of the U.S. Geological Survey. More recently a discussion of the mineralogy and petrogenesis of the dike system was completed by the author (Foord, 1976).

Mining operations on the Himalaya dike system began on the Himalaya claim in 1898, with the collecting of surface material by Gail Lewis. Shortly thereafter, opencut work was begun. In 1899 tourmaline was discovered on the San Diego property, also by Gail Lewis. In 1902, the Himalaya property was taken over by J. L. Tannenbaum, and J. Goodman Braye supervised much of the subsequent mining. By about 1904, surface work was essentially completed and subsequent mining was entirely underground.

During the three years after the discovery of tourmaline on the San Diego property, several opencuts and trenches were excavated by K. C. Naylor and A. L. Ross. In 1902, underground work was begun and the San Diego Tourmaline Mining Company was organized in 1904 to work the deposits. Work proceeded at an extremely rapid pace and by 1910 nearly all of the old underground workings on the property had been developed. The collapse of the Oriental tourmaline market in 1912 resulted in bankruptcy and cessation of work on both properties. Between 1912 and 1960 mining and excavation at the San Diego mine was limited in large part to short inclines, in general less than 100 feet long, and to tunnels and cuts. Most of the work was done by Fred J. Rynerson or under his supervision. During the period between 1925 and 1928 the General Electric Company, with F. J. Rynerson acting as mine foreman, excavated two holes along with the General Electric tunnel in the Himalaya mine.

Some additional work was done between 1933 and 1950 by E. B. Rynerson and B. F. Rynerson, and in 1934 by Arthur Montgomery and Edwin Over at the San Diego mine. In 1960, Eugene B. Rynerson, initially with the assistance of his nephew, Alan Rynerson, began full-time operation of the San Diego mine by driving a new tunnel some 30 feet below the level of the old Naylor workings. To date, a total of approximately 1500 feet of workings have been developed.

Minerals were identified largely by touch, because of poor lighting conditions. Many excellent beryl crystals and smooth-faced crystals of tourmaline were discarded on the dumps because they *felt* like quartz crystals...

Some small scale work was done by Thomas A. Quinn at the Himalaya mine until his death in 1938. Herbert C. Hill was an unofficial caretaker during the 30's and 40's until he died in 1952. Contrary to popular belief, Hill was not responsible for any appreciable amount of work except for two inclines in the southern part of the property that were sunk by him in 1945 and 1948. The Himalaya mine was acquired by Ralph R. Potter from the Quinn family in 1952 and was operated by him until 1963, using Mexican labor. Several old inclines and tunnels were reopened and additional new work was done as well. At this time, 1963, the Himalaya mine was divided into 10 shares and sold to various parties, Potter retaining two of the 10 shares.

After the main portal of the Himalaya mine collapsed during the wet season of 1968-69, some surface work (backhoe) was done by the Himalaya Mining Corporation, as underground activity there was no longer practical. During the period 1971-74 a new portal was excavated on the east side of Gem Hill to reopen the old "hard rock" tunnel. Recently the tunnel was extended from the lower dike to the upper dike, and some cross-drifting along the dikes was done.

It is worth commenting here on the evolution of mining methods used in the Himalaya dike. The first work consisted of pick and shovel excavation with a little blasting. Loose blocks of dike rock on the surface were processed for their possible content of gem tourmaline. This work evolved into shallow opencut activity along the strike of the dike system. Material was mined down dip as far as was practical to strip off the overlying soil and decomposed norite. Following this, underground work was extended down dip in favorable areas, and thence along strike. Because of the lack of tungsten carbide drill bits and modern drilling machinery, work was at first limited to about 100 feet or so down the incline where the norite above and below the dike was sufficiently weathered to permit hand drilling. Chunks of dike rock were then blasted out and examined underground. Minerals were identified largely by touch, because of poor lighting conditions. Many excellent beryl crystals and smooth-faced crystals of tourmaline were discarded on the dumps because they *felt* like quartz crystals, and for years afterward this material was scavenged from the dumps. Depth was also limited to about 100 feet on the incline owing to the necessity of hand winching.

It was not until the 1950's, when hard-faced drill bits became readily available, that deeper mining activity in fresh norite was economically feasible. The San Diego mine was excavated with the use of compressed-air-driven jackhammers and tungsten carbide insert drill bits. Similar methods have recently been used in the "hard rock" tunnel by the Himalaya Mining Corporation.

The author has inspected and studied the accessible workings on both properties, and has assisted both organizations in the mining activity.

Table I: Minerals from the Himalaya pegmatite-aplite dike system

Aplite zone	Graphic pegmatite zone	Pocket pegmatite zone	
		Primary minerals	*Secondary minerals*
Quartz	Same as for the Aplite zone, with the addition of locally developed schorl-elbaite.	Quartz	Quartz
Garnet		Spessartine	Muscovite
Plagioclase		*Cleavelandite* (albite)	Rynersonite
Microcline		Microcline	Fersmite
Tourmaline		Orthoclase	*Sn-Microlite*
Muscovite		Schorl-Elbaite	Cookeite
Spinel (gahnite)		Muscovite	Beyerite
		Lepidolite	Hambergite
		Morganite (beryl)	Bavenite
		Columbite-Tantalite	Herderite
		Stibiocolumbite	Thorogummite
		Stibiotantalite	Stokesite
		Topaz	Montmorillonite
		Apatite	Kaolinite
		Uranmicrolite (microlite)	Leonhardite
		Microlite	Laumontite
		Djalmaite (microlite)	Stilbite
		Monazite	Thomsonite
		Zircon	Heulandite
		Pollucite	Todorokite
		Cassiterite	

Varietal names in *italics*; mineral group names in **bold**.

STRUCTURE

Each of the dikes is asymetrically zoned both vertically and horizontally with respect to mineral content, grain size, and crystal habit (Fig. 6). Perhaps the most striking mineralogical changes along strike are in the amount and distribution of potash feldspar. Within the San Diego mine, the upper dike contains relatively minor amounts of microcline in its upper portion. The great bulk of potash feldspar that is present occurs in lower areas, beneath the pocket zone. Within much of the upper dike on the Himalaya property to the north, numerous tapered crystals of potash feldspar are present along the upper margin and flare downward. The footwall portions of both dikes in the Himalaya mine contain lower proportions of potash feldspar than the footwall portions within the San Diego mine. The relative abundance of potash feldspar is greater on the north end of the dike system than on the south.

A second notable horizontal variation within the dike system is shown by the quality and quantity of gem and specimen materials within the pocket zone. The north end (Himalaya mine) has yielded the largest quantities of pocket minerals, as well as those of best quality.

The lower two-fifths of the combined pair of dikes are composed largely of non-layered aplite that is relatively coarse grained and structureless. It is overlain by finer grained pegmatitic aplite (aplite containing some large crystals) that is compositionally layered on a fine scale (0.X to X.0 inches). The pegmatitic aplite grades upward into a zone of coarse grained, massive to graphic pegmatite that fills the remainder of the dikes. The central portion of each dike (pocket zone) is characterized by large crystal size, chemical and color zonation in tourmaline, garnet, micas and other minerals, and by the occurrence of numerous rare mineral species. Within this zone are clay-filled

Figure 7. (left) **Potassium feldspar crystal with cleavelandite, from the Himalaya dike. Photo by O. D. Smith.**

cavities, inches to several feet in maximum dimension, that contain free-standing euhedral crystals.

MINERALOGY

The minerals indicated in Table 1 represent all species positively identified in the course of the present investigation (Foord, 1976, which see for further descriptions and analytical procedures). At least three heretofore unknown (not previously described from the Himalaya dike system) or new minerals also were identified. **Rynersonite**, $Ca(Ta,Nb)_2O_6$, is a new species (Foord and Mrose, 1978, in press), and **stokesite**, $CaSnSi_3O_9 \cdot 2H_2O$, and **fersmite**, $(Ca,Ce,Na)(Nb,Ta,Ti)_2(O,OH,F)_6$, are minerals new to California. **Djalmaite, stannian microlite, beyerite, thorogummite,** and **todorokite** have not been reported previously from the dike system.

Quartz SiO_2

Quartz is a ubiquitous mineral within the dike system and varies widely in grain size, habit, and other properties. Quartz from the aplitic rocks is generally anhedral to subhedral, whereas that from the pegmatite portions and pocket pegmatite portions is generally subhedral to euhedral (Fig. 5). Some crystals of pocket quartz are more than 8 inches in length. Areas of clear material are interspersed with milky areas in many crystals, but the tips of crystals generally are clear. Most of the quartz is colorless or milky white but some yellow and smoky material has also been found. Pocket quartz crystals are usually elongate prismatic with well developed trapezohedral and rhombohedral faces. Formation of quartz evidently occurred at all times during evolution of the dike system, and it is one of the last minerals to have ceased growth.

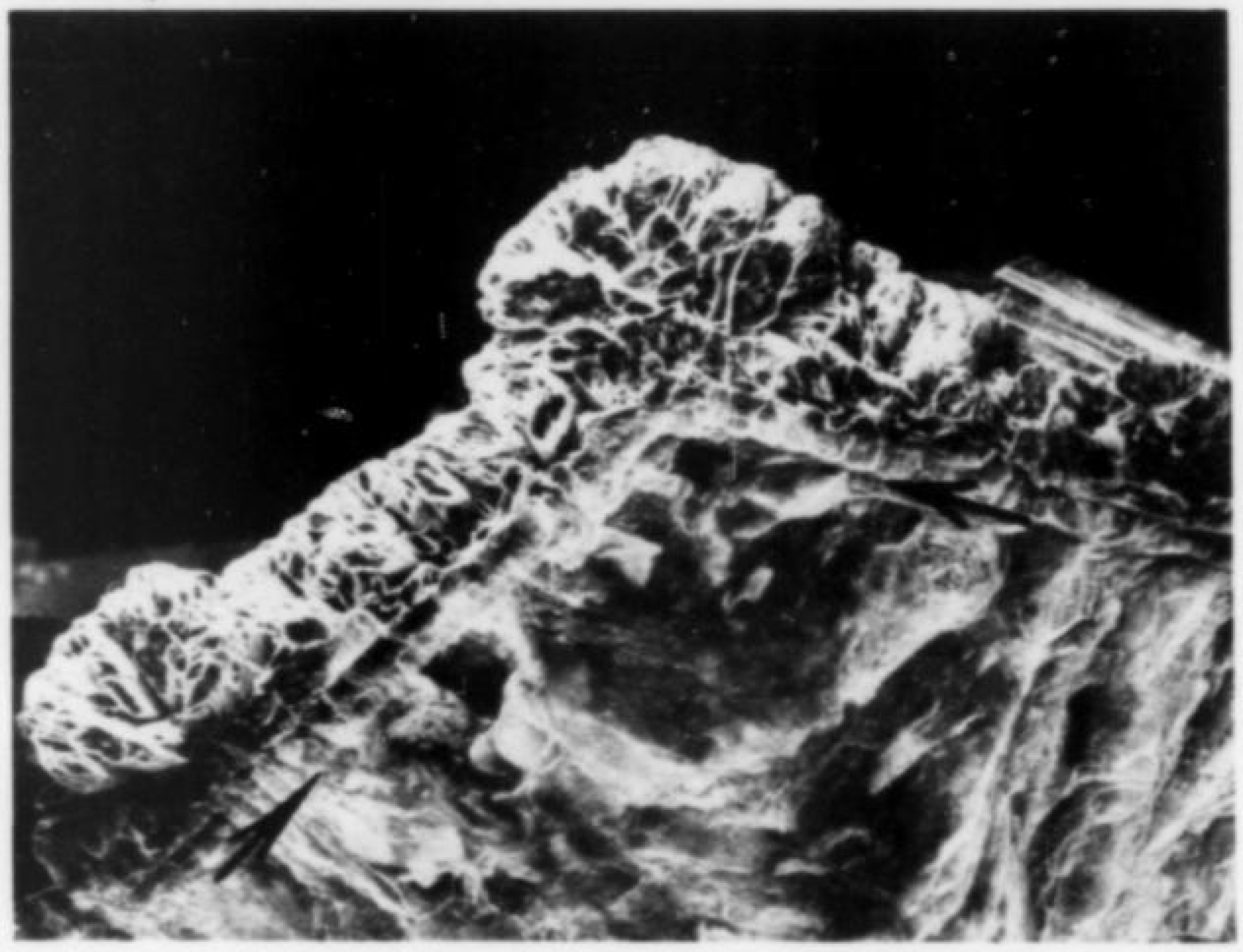
Feldspars $(K,Na)AlSi_3O_8-CaAl_2Si_2O_8$

The alkali and plagioclase feldspars together constitute the most abundant mineral group within the dike system. Both feldspars show progressive compositional shifts. Plagioclase within the footwall aplite has a composition of about An_{10}, as does that in the hangingwall graphic pegmatite. In albite of the pocket zone, the composition is An_1 or less, the crystal habit becomes that of cleavelandite (Fig. 8), and freshly broken surfaces commonly are pale blue or green in color. Alkali feldspar (maximum microcline) within the footwall aplite and hangingwall pegmatite has a composition of about Or_{93}, which shifts abruptly to about Or_{97} within the pocket zone. Many pocket crystals of microcline are coated with an overgrowth of transparent, glassy feldspar that has been shown to be nearly fully ordered orthoclase (Prince, Donnay, and Martin, 1973) with a composition of about Or_{90}. The contacts between these overgrowths and the host microcline crystals are sharp to gradational over distances of as much as one-quarter inch. The overgrowth is not equally developed on different faces of a given host crystal.

The crystals of potash feldspar range from less than 0.1 inch to a foot or more in maximum dimension, whereas the range for albite is only about 0.1 inch to 1 inch. Graphic texture is well displayed by quartz and microcline within the

Figure 8. (above) **A circular plate of white albite attached to a pink crystal of tourmaline from the Himalaya mine. The albite crystal is 3 cm across. Smithsonian specimen, NMNH# 118174; photo by Wendell Wilson.**

Figure 9. (below) **A crystal of muscovite (bottom) with an epitaxial layer of lepidolite (pinkish purple). The specimen as shown is about 6 cm wide. The arrows mark the contact between lepidolite and muscovite. Smithsonian specimen, NMNH# R17237. Photo by Wendell Wilson.**



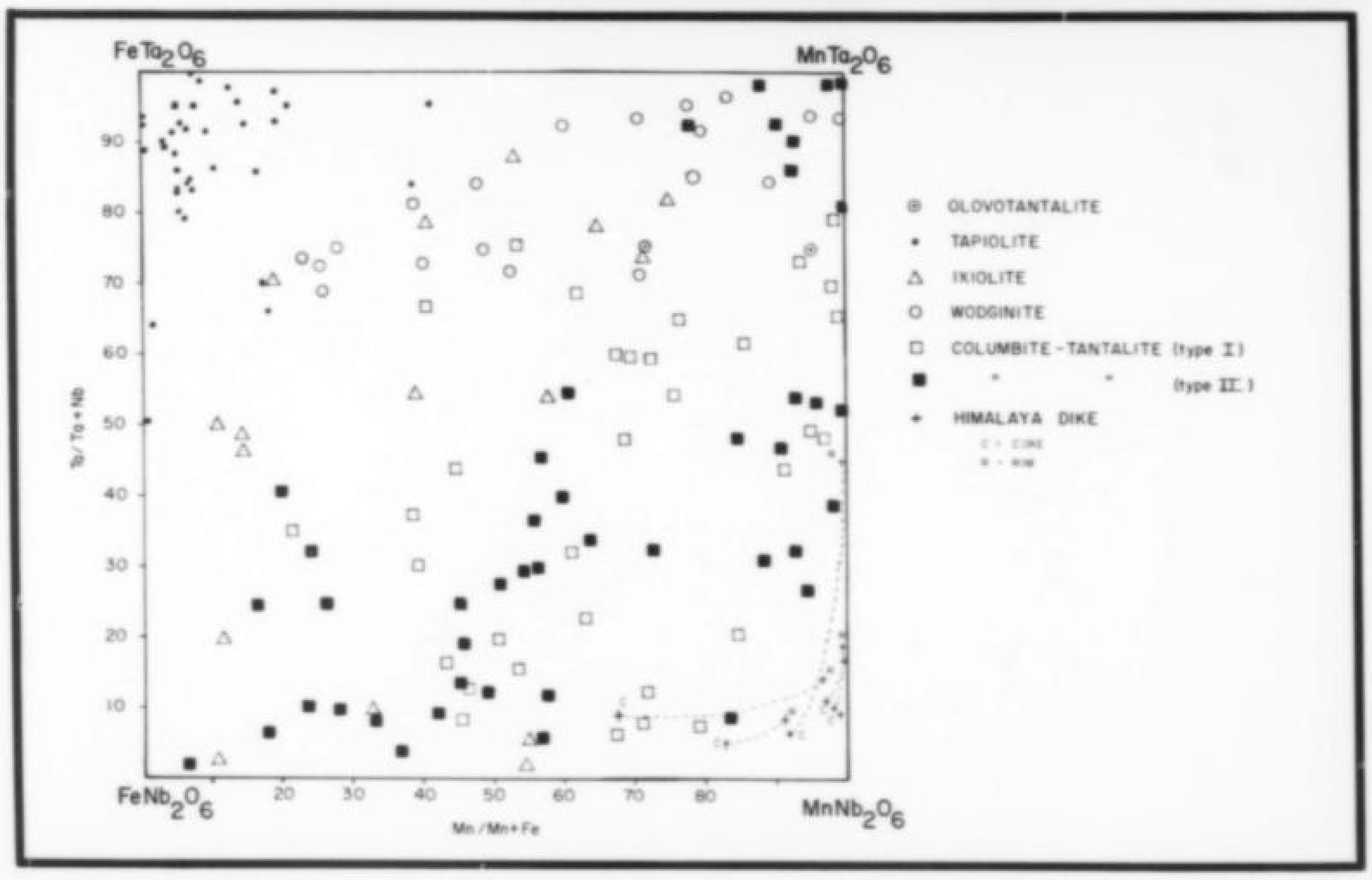


Figure 10. (right) **A compilation of analyses of columbite-tantalite group minerals of known structural type. All analyses were taken from published literature except those for the Himalaya dike system, which were made as part of this study.**

pegmatite portions of the dike system, particularly within the large tapered crystals of potash feldspar. Lacy and dendritic texture is shown by the albite particularly well within the hangingwall pegmatite portions of both dikes, and to a lesser extent below the pocket zone.

Pocket-zone potash feldspars generally show evidence of corrosion, and boxwork texture is widespread (Fig. 7). Some of the large crystals of perthite are distinctly cellular in appearance, the microcline having been etched out to leave a reticulate network of albite parallel to (010) and (001) of the host. Crystals outside of the gem pockets do not generally show evidence of later corrosion and replacement of the type seen within the pockets.

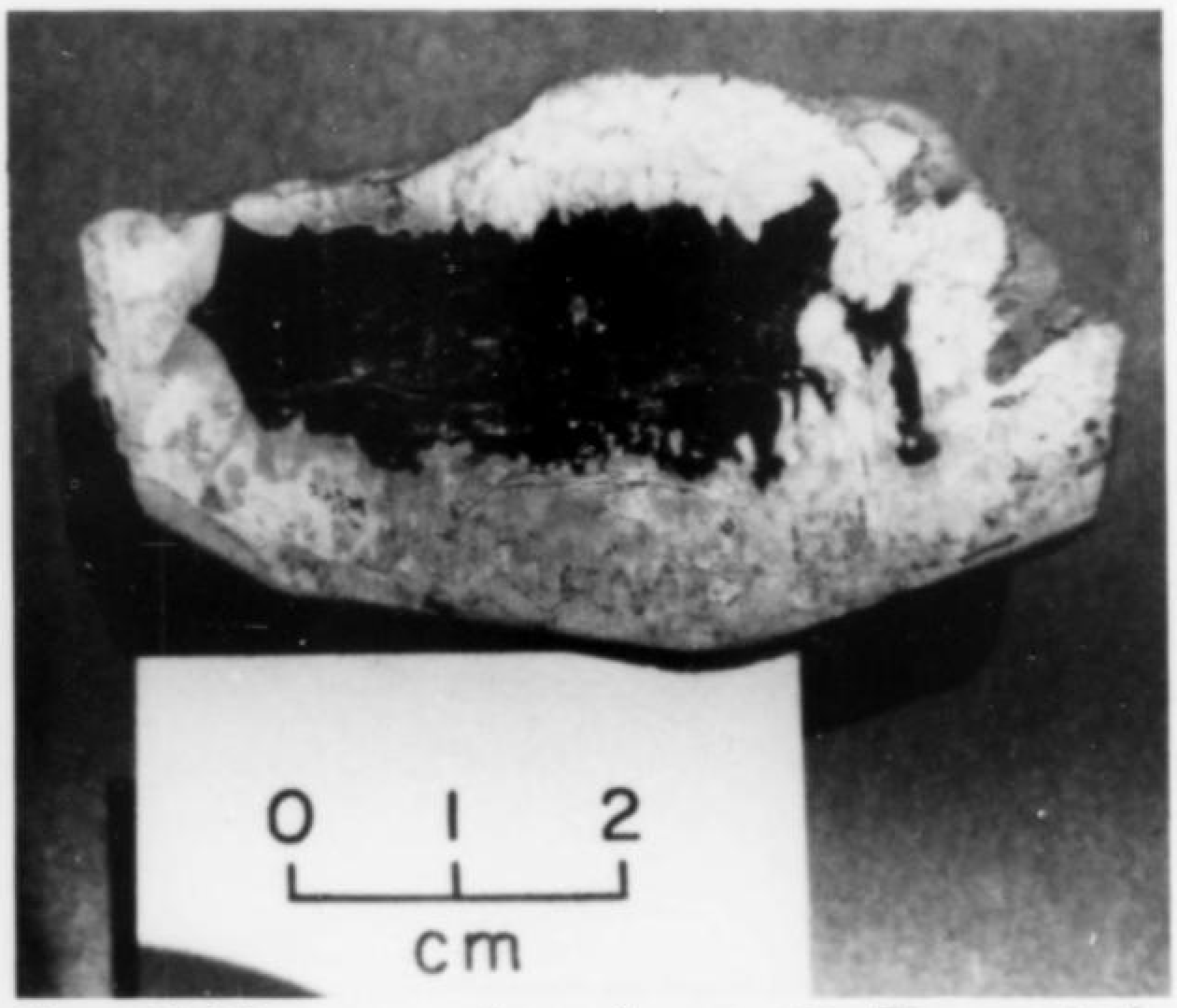


Figure 11. **The type specimen of rynersonite. The area in the center is dark yellow-brown stibiotantalite, surrounded by a light-colored border of rynersonite with a thin, discontinuous rim of fersmite. The specimen is 6.5 cm long.**

Only crystals of potash feldspar from the pocket zone have smooth and regularly developed faces. Phantom crystals, outlined by very thin, dust-like coatings of muscovite, schorl, or garnet, are locally abundant. Most of the microcline is white, gray and flesh-colored, but some pocket crystals are a deep tan in color. The dominant faces on most of the pocket feldspar crystals are the base, clinopinacoid, prisms, and orthodomes. Small pyramidal faces are not uncommon. In addition to the lamellar albite and pericline twinning of the microcline, many of the potash feldspar crystals are twinned according to the Carlsbad law, Manebach law or Baveno law.

Garnets (almandine-spessartine) $Fe_3Al_2(Si_4O)_3$—$Mn_3Al_2(SiO_4)_3$

Almandine-spessartine garnet is relatively abundant and appears to have crystallized throughout nearly all of the primary development of the dike complex. It is most common within the layered aplite and accompanying fine-grained pegmatite, where it ranges in composition from $Alm_{73}Spess_{24}Pyr_3$ to $Alm_{49}Spess_{50}Pyr_1$. Within the pocket pegmatite zone, in contrast, the garnet is nearly pure spessartine, $Alm_{0.5}Spess_{99.5}Pyr_0$, and is a distinctive light orange in color. The maximum grain size is greater than 1 inch across, but rarely is the garnet found as gem-quality material suitable for cutting.

Almandine-spessartine garnet is present in the non-layered and layered aplite as dodecahedral and trapezohedral crystals 0.01 inch to 0.1 inch in diameter. Somewhat larger crystals are present within the graphic pegmatite portions of the dikes but are less abundant. Though dominantly dodecahedral and trapezohedral in form, many of the pocket crystals also show well developed trisoctahedral faces.

Garnet within the layered aplite-pegmatite and the non-layered aplite has a mean composition of about $Alm_{50}Spess_{50}$, with only minor zoning present within individual grains, although some exceptions have been found. Major changes in the Mn:Fe ratio do not occur within the dikes until just above or below the pocket zone. Garnet within the hangingwall graphic pegmatite shows compositions similar to those within the layered aplite sequence, as well as developing compositions rich in the spessartine component. Crystallization evidently ceased with formation of nearly pure spessartine during the early stages of pocket development.

Micas

Muscovite, $KAl_2(AlSi_3)O_{10}(OH)_2$, and lepidolite, $K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$, of polymorphic types $2M_1$ and 1M respectively, are the most common members of the mica group minerals in the Himalaya dike. Lesser amounts of biotite, $K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$, exist near the edges of the dikes. Lepidolite is found only within the pocket zone and is further restricted to domains of pink tourmaline, whereas muscovite is present in all three zones. Green tourmaline pockets contain only muscovite, commonly as crystals with colorless to pink-violet to colorless zoning. Lepidolite occurs as epitaxial overgrowths on muscovite books (Fig. 9) and as isolated scaly masses. All lepidolite thus far observed is purple-violet in color. The largest individual books of muscovite and lepidolite are about 3 to 4 inches wide and ¾ inch thick. Lepidolite also occurs as rims around grains of spessartine that occur above and below the center of the pocket zone. This is a local phenomenon apparently controlled by exclusion of Mn^{+3}, and perhaps higher valence states of Mn as well, from spessartine to create a "front" favorable for the formation of lepidolite containing as much as 4% MnO.

Cookeite, $LiAl_4(AlSi_3)O_{10}(OH)_8$, a member of the "brittle micas," occurs sparingly within the pocket zone. It is a late-stage alteration product of lepidolite and tourmaline, and forms coatings on these and other pocket minerals. The maximum

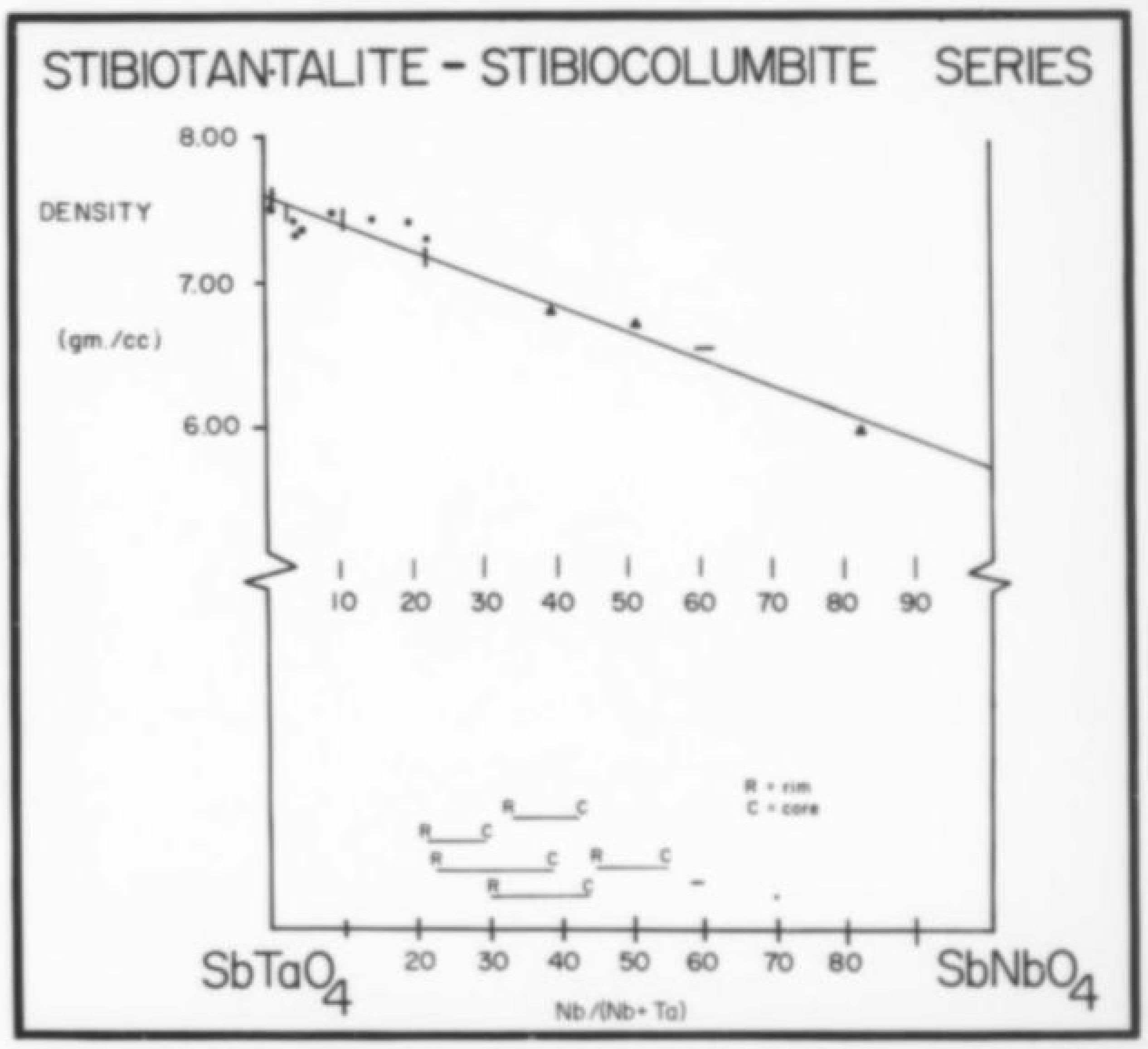


Figure 12. **A compilation of analyses in the stibiotantalite-stibiocolumbite series. Solid dots represent analyses from localities other than the Himalaya dike system. Triangles represent previously published analyses from the Himalaya dike system. Analyses at the bottom (density not determined) are from this work.**

grain size is about 0.1 inch; the crystals are colorless to pale pink in color and often show hexagonal outlines.

Niobium-Tantalum Oxides

Nb-Ta oxides are a minor but distinctive mineral group occurring within the dike system. **Columbite-tantalite, stibiocolumbite-stibiotantalite, djalmaite-uranmicrolite, microlite, rynersonite, fersmite,** and **stannian microlite** have been positively identified. Several of these minerals are compositionally unique among reported world occurrences.

Columbite-Tantalite $(Mn,Fe)(Nb,Ta)_2O_6$

Analyses of specimens from this mineral series indicate that compositions range from nearly pure $MnNb_2O_6$ to $Mn(Ta_{.5}Nb_{.5})_2O_6$. Compilation of all available analyses from this series shows that Himalaya dike material is unique in composition (Fig. 10). Only a few analyses of material from elsewhere in the world approach $MnNb_2O_6$ (manganocolumbite), whereas much of the Himalaya material examined is of that composition.

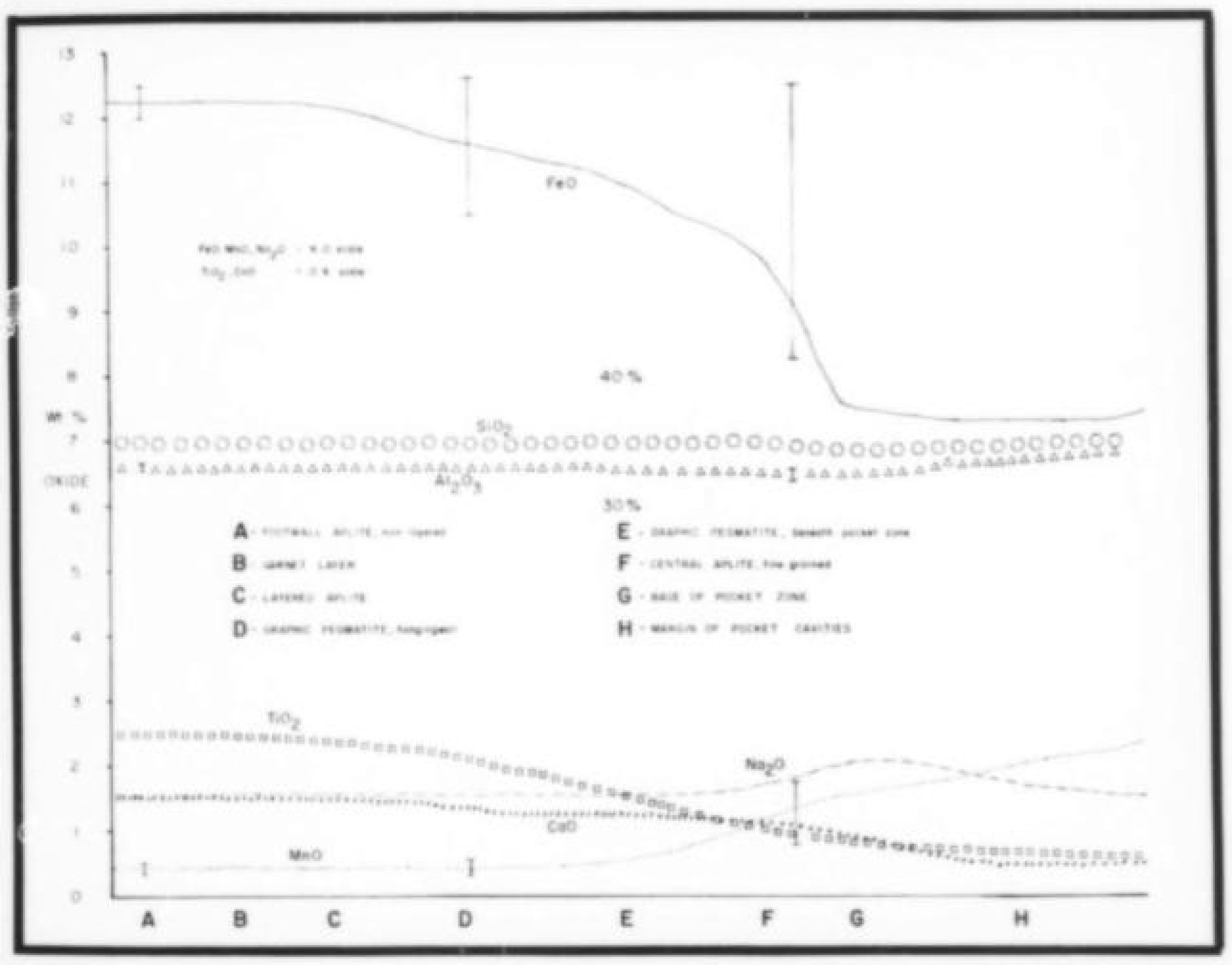


Figure 13. **Oxide variation within tourmaline from the Himalaya dike system.**

Most of the columbite is enclosed by other pocket-zone minerals, and euhedral, free-standing crystals are rare. Crystal sizes up to 1 inch by one-half inch by 2 inches have been reported. The crystals are generally lustrous and characteristically submetallic, particularly on broken surfaces. Many of the crystals are plates which are flattened parallel to the side pinacoid. Other individuals, in contrast, are nearly equidimensional or tabular in habit. Some have been partially altered to rynersonite-fersmite (Fig. 11), which forms a fine-grained cream to flesh-colored coating.

Stibiocolumbite-Stibiotantalite $Sb(Nb,Ta)O_4$

Figure 12 is a plot of available analyses of stibiocolumbite-stibiotantalite from both the dike system and other localities. In almost all the other localities, the minerals of this series are extremely rich in tantalum. If it were not for the stibiocolumbite from the Himalaya dike, one might reasonably question the existence of a complete solid-solution series between the two end members.

As in the case of the columbite-tantalite examined, the Nb/Nb+Ta ratio decreases steadily from cores to rims of individual crystals. Values for this ratio are given in Figure 12. The Himalaya mine is world-famous for its production of fine, euhedral crystals of stibiocolumbite-stibiotantalite. Crystals up to 2 inches by 0.5 inch by 2 inches have been reported. Some of the crystals have been partially altered to rynersonite and/or fersmite. Figure 11 shows a specimen of stibiotantalite partially replaced by rynersonite that in turn has an alteration rind of fersmite. Crystals are generally tabular to equant in habit and show characteristic resinous to almost adamantine luster. The tabular crystals are flattened parallel to the side pinacoid. Domal and basal faces are well developed on some individuals. Many of the crystals are polysynthetically twinned on the side pinacoid, and this twinning is readily observed on pyramidal faces.

Djalmaite-Uranmicrolite-Microlite $(U,Ca,Na)(Ta,Nb)_2O_6(OH,O,F)$

Djalmaite, a variety of microlite, is very rare within the Himalaya dike system and has been detected only as extremely small grains less than 0.01 inch across. By definition, djalmaite has uranium as the most abundant A site cation except for possibly Ca+Na. Because of the extremely high U content (about 32%), the mineral is metamict. The habit of the few grains observed was equant and subhedral.

Uranmicrolite-microlite crystals are distinctive in their color, habit, radiation damage effects, and other characteristics. They occur only within the pocket zone of the dike complex. Octahedral crystals up to nearly 0.5 inch in maximum dimension have been observed in association with lepidolite or quartz. Some minor but sharply developed dodecahedral, trisoctahedral, and trapezohedral faces may also be present. The larger crystals are honey-yellow to light yellow, and the grains of uranmicrolite are dark brown to black. Radiation "burns" are readily observable around grains of the uranmicrolite variety in quartz and tourmaline. Composite uranmicrolite-microlite crystals may have metamict or partially metamict cores and crystalline exteriors. As in the case of the other primary Nb-Ta oxides from the dike system, the Nb/Nb+Ta ratio decreases from cores to rims of individual crystals.

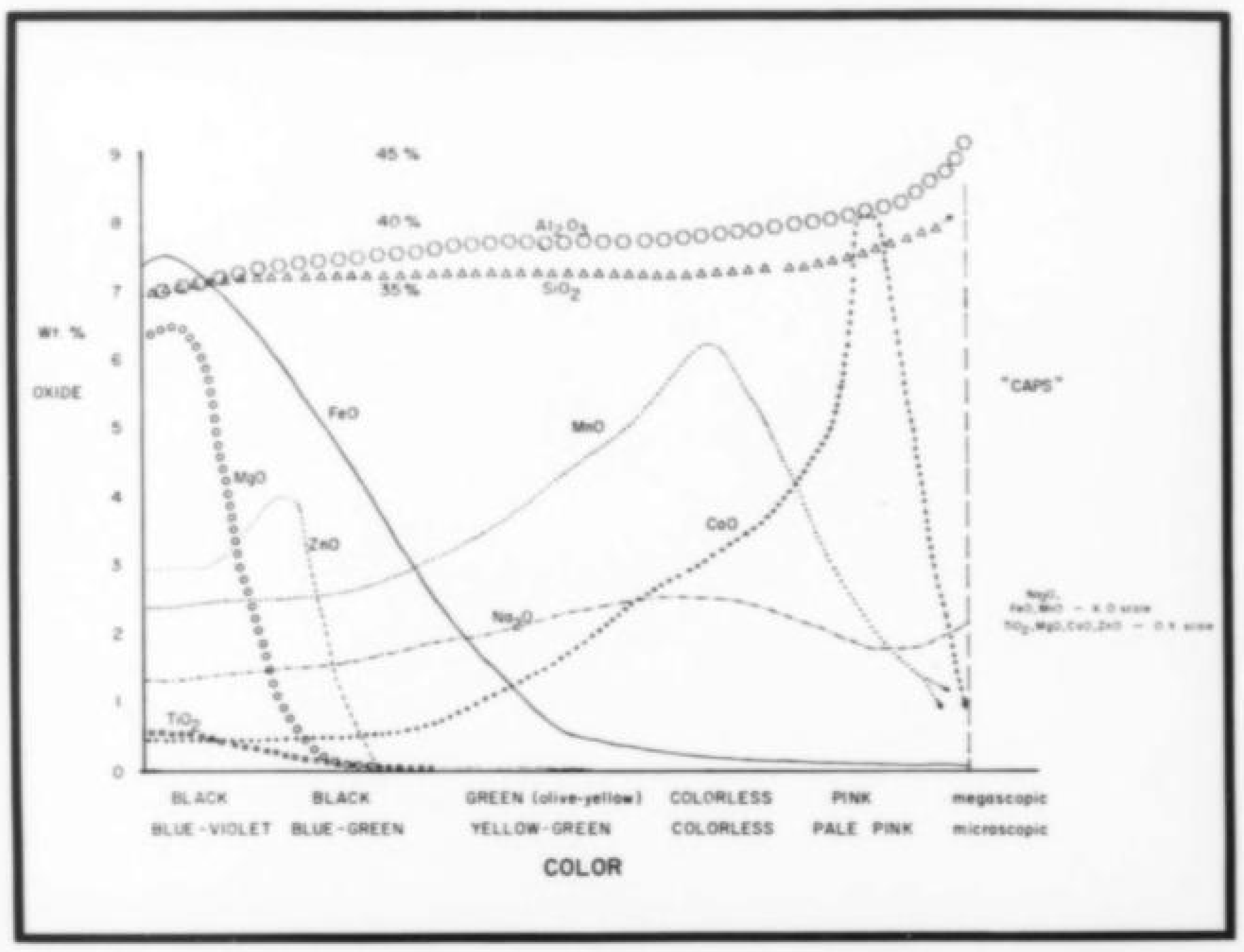


Figure 14. **Oxide variation within pocket tourmaline crystals from the Himalaya dike system.**

Rynersonite $Ca(Ta,Nb)_2O_6$

Rynersonite is a new mineral species (Foord and Mrose, 1978, in press) named in honor of the Rynerson family, members of which have operated mine workings in the Himalaya dike since the turn of the century. $CaTa_2O_6$ (rynersonite) and $CaNb_2O_6$ (fersmite) do not form an isomorphous solid-solution series. The space group for rynersonite is *Pmnb*, but that for fersmite is *Pbcn*. The mineral occurs as an alteration product of stibiotantalite and, to a lesser extent, of tantalite. It is extremely fine grained and ranges in color from buff-cream to pinkish red. Rynersonite may occur singly or more commonly as intergrown masses of slender acicular crystals.

Fersmite $(Ca,Ce,Na)(Nb,Ta,Ti)_2(O,OH,F)_6$

Fersmite is a rare species hitherto not reported from California. It occurs with or without rynersonite which it resembles in general appearance. The mineral is also extremely fine grained, cream to light buff-pink in color, and has an acicular habit. However, it is strongly fluorescent (blue) in ultra-violet light, whereas rynersonite is not.

Stannian microlite $(Ca,Na,Sn,Sb)(Ta,Nb)_2O_6(OH,O,F)$

Sn-bearing microlite with or without some antimony occurs as an alteration product of several Nb-Ta oxides. It is similar in appearance to rynersonite and fersmite, and commonly is admixed with either or both. The mineral is very fine grained (less than 0.01 inch across), pale yellow to cream-buff in color, and has an equant habit.

Tourmalines **(schorl)** $NaFe_3^{2}Al_6(BO_3)_3Si_6O_{18}(OH)_4$
(elbaite) $Na(Li,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH,F)_4$
(dravite) $NaMg_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Tourmaline of the schorl-elbaite series is a widespread mineral within the Himalaya dike system. It occurs as euhedral, elongated prisms, black to pink in color. Crystal size within the footwall aplite (layered and non-layered) is generally less than ¼ inch in maximum dimension, while that within the pegmatite and pocket pegmatite zones is an order of magnitude larger or more. Locally, schorl-dravite is developed within the adjacent hydrothermally altered norite wallrock and occurs as slender, elongated, black prisms as large as 3 inches in length and ¼ inch in diameter.

Chemical zonation within schorl-elbaite crystals was examined in detail by electron microprobe methods. Figure 13 is a summary of observed chemical trends as correlated with tourmaline location for various occurrences in the dike system. Staatz, Murata and Glass (1955) were the first to document changes in the chemistry of tourmaline according to its position in a zoned pegmatite body. Until now, however, there has been little quantification of elemental trends or monitoring of all major elements. The principal changes are in contents of Mn, Fe, Al and Ca, which evidently increased at the expense of Fe with continued development (crystallization) of the pocket crystals. The corresponding color sequence, as typically observed in singly terminated pocket zone crystals, is black → blue → blue green → green → yellow → colorless → pink (Figure 14). The clear "caps" that are so prominent on many gem crystals of Himalaya tourmaline must represent a marked change in pocket conditions (Fig. 14). The chemistry of the caps is a repeat of the trend already noted, although not necessarily with the same absolute element abundances. It can be thought of as a result of a resetting of a chemical clock. Depending on the local pressure, temperature and composition conditions, pocket rupture as hypothesized by Jahns and Burnham (1969) may have occurred as early as the achroite stage of development or as late as the rubellite stage. Evidence has been found in some pockets for secondary, and even for tertiary or later episodes of rupture (pocket failure). The well-known "pencil" tourmalines, generally of gem quality, evidently were formed at the same time as the caps and overgrowths on the primary crystals that line the pocket cavities (Figure 15). The larger crystals of tourmaline seem to have nucleated on the upper surfaces of these cavities, smaller and more scattered crystals on the cavity floors.

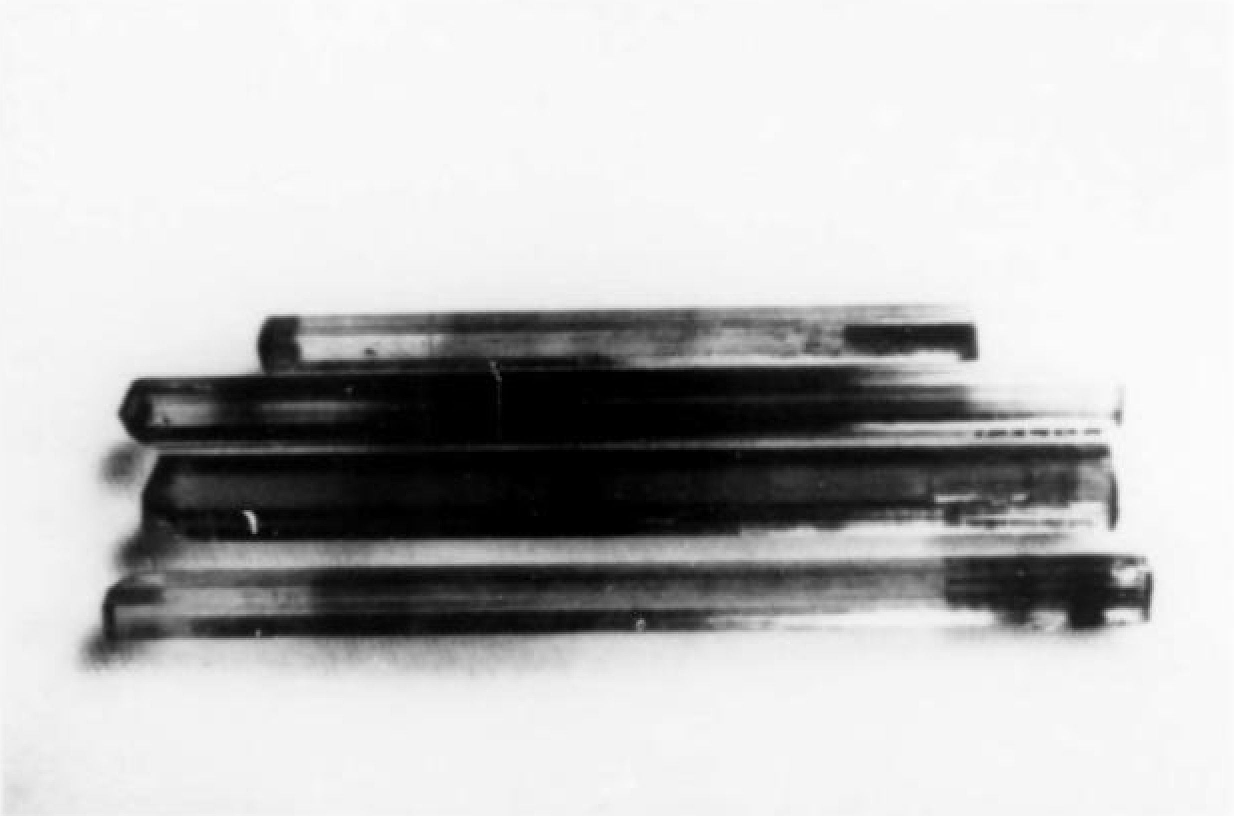


***Figure 15.* "Pencil" tourmaline (elbaite) from the Himalaya mine. The terminated ends on the left are green and the darker portions of the crystals on the right are red; the longest crystal is 7 cm. Smithsonian specimens; photo by Wendell Wilson.**

Most doubly terminated crystals, for which the Himalaya dike system is world-famous, appear to have formed after pocket rupture and simultaneously with the pencil tourmalines. The properties of pyroelectricity and piezoelectricity may well have been mainly responsible for the different colors (and compositions) on opposite ends of these crystals. Presumably, Fe^{+2} (green chromophore)* was preferentially attracted to the analogous pole (pole of less negative charge), while Mn^{+3} (pink or red chromophore) was attracted to the pole of maximum negative charge (antilogous pole). Mn^{+2} is not necessarily a chromophore by itself, as witness achroite (colorless tourmaline) with more than 6% MnO! During the growth of primary crystals, the composition was controlled by the pocket solution chemistry, however, subsequent to pocket rupture and crystal breakage, growth is controlled not only by the solution chemistry but also by the pyroelectric and/or piezoelectric effects which become manifest. Tourmaline is non-centric and possesses the properties of pyroelectricity and piezoelectricity. As the pressure and temperature returned to more ambient conditions (those conditions within the surrounding dike material), final material crystallized is again controlled only by the solution chemistry, and the last material to form on a doubly terminated crystal of tourmaline has the same composition at either end and along the sides.

Crystals of tourmaline within the pocket zone and particularly those within open cavities are all sharply faced, especially in the prism zone. There are all gradations from single, deeply striated prismatic crystals to composite crystals that consist of several united but slightly divergent individuals that evidently grew from a common base. Individual crystals range from tiny needles less than 0.25 inch long to thick prisms as much as 15 inches long and 3 inches in diameter. Few, however, are more than 6 inches long and 2 inches in diameter. Elbaite crystals are typically associated with quartz, microcline-orthoclase, cleavelandite, muscovite and/or lepidolite.

Most pocket crystals of tourmaline show pronounced hemimorphism with the simple (0001) pedion face being most well developed on the positive termination (positive pole) while rhombohedral and scalenohedral faces are developed on the negative terminations (negative pole) if the crystals are doubly terminated. Undulatory and step-like (raised) features commonly observed on the pinacoid faces of tourmaline crystals are some of the most striking and interesting growth phenomena found. Figure 16 shows examples of these features. The growth "hills" or "spirals" often reflect the trigonal morphology (R3m) of the mineral.

As the growth velocity increases, morphology changes from planar to cellular or even dendritic. Conditions of extremely rapid growth produce distinctive "catseye" tourmaline, "catseye" being defined as tourmaline possessing a silky sheen and chatoyancy due to the presence of numerous oriented, elongate,

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*chromophore = the coloring agent of a mineral.

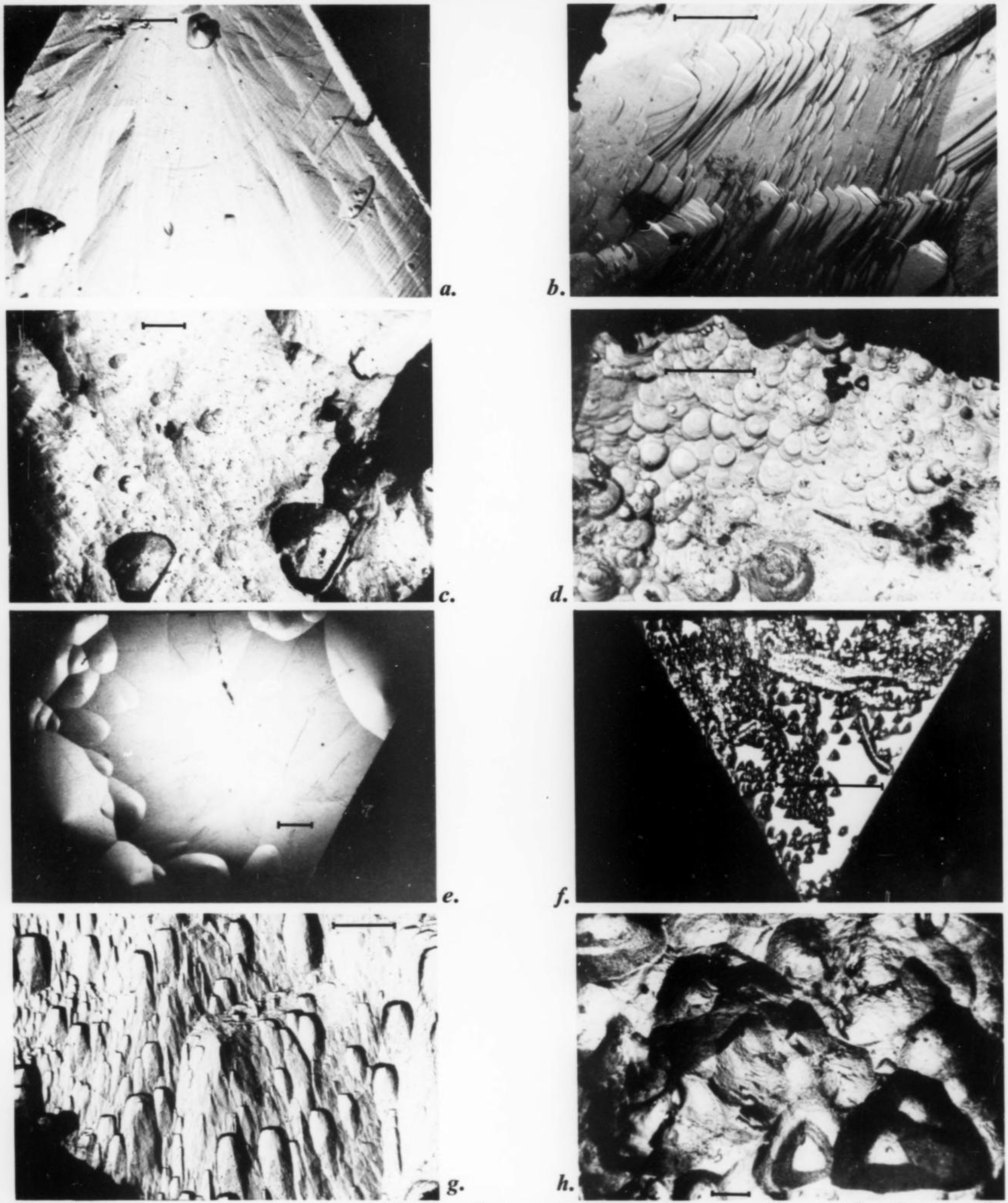


Figure 16. **Growth features on termination faces of Himalaya dike tourmaline; the scale bars represent 1 mm.** ***(a)*** **Growth cones on the {0001} face of a "pocket" rubellite with a light green cap, from the "pink area" of the San Diego mine.** ***(b)*** **Steeply pitched growth hills on the {1011} face of a "pocket" olive-green to colorless crystal from the San Diego mine.** ***(c)*** **Growth cones on the {0001} face of a "pocket" olive-green to colorless crystal from the San Diego mine.** ***(d)*** **Trigonal growth cones on the {0001} face of a "pocket" crystal, olive-green to colorless, from the San Diego mine.** ***(e)*** **Growth hills on the {0001} face of a doubly terminated rubellite crystal with a medium-green cap, from the Himalaya mine.** ***(f)*** **Growth hills on the {0001} face of a doubly terminated, colorless to red crystal from the "pink area" of the San Diego mine.** ***(g)*** **Growth cones on the {0001} face of a doubly terminated rubellite crystal with a medium-green cap (same crystal as in e.)** ***(h)*** **Inclined growth hills on the {1021} face of a rubellite crystal with a thin, light green cap, from the Himalaya mine. Foord photos and specimens.**

tubular cavities parallel to the *c* axis. Catseye material may be grown upon any colored substrate, but it does so with a very sharp contact. Some transitions between clear and milky material are gradational over ¼ inch or less.

Sector zoning, in conjunction with twinning on {1011}, is only rarely observed within tourmaline from the Himalaya dike system, and then only in pencil and catseye materials. This phenomenon may be due to secondary pyroelectric and/or piezoelectric effects (temperature and pressure gradient over the length of a crystal), or to preferential site occupancy reflecting lattice energies and bonding energies.

Figure 17 shows a pocket filled with gem and specimen-quality pink tourmaline immediately before extraction. Note the jackstraw distribution and fractured nature of the crystals. The surrounding matrix is principally montmorillonite. Crystals from this pocket weighed as much as 0.5 pound each, with dimensions on the order of 2 inches by 6 inches.

Mechanical deformation of tourmaline is shown by bent, twisted, and otherwise deformed primary crystals containing fractures filled with material having the same composition as the 'caps' on such crystals (Fig. 18). Some crystals within pockets were not completely broken off from the walls, but nevertheless were deformed in a brittle manner. This phenomenon is of great interest and is seen in other gem pegmatites within San Diego County as well. Such deformation is thought to have occurred at the time of primary pocket rupture when solutions were allowed to flow through pocket cavities with some violence.

Beryl $Be_3Al_2Si_6O_{18}$

The Himalaya mine has produced many fine morganite crystals, some of which have been corroded and etched, while still others have been partially or wholly altered to bavenite and other secondary minerals (Fig. 20). The color ranges (when unaltered) from a peach-orange to a delicate strawberry-pink (see photo in Larson, this issue), and the habit, typical for morganite, is squat and tabular, flattened parallel to *c*. The maximum crystal size reported is on the order of 5 inches by 3 inches by 4 inches. It has been found that the total content of alkalies increases while BeO decreases as crystallization of beryl progressed.

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

Fine specimens of apatite also have been obtained from the dike system, including a few of gem quality. The color ranges from a light pink to a deep wine-red for some crystals, and from pale sky-blue to medium blue for others. Some pockets contain apatite crystals with pink centers and blue rims. The contact between the two colors is sharp and is analogous to the green caps on pink tourmalines. As in the case of tourmaline, this is thought to reflect changing conditions at the time of pocket rupture. Most of the apatite found is strongly fluorescent under ultraviolet light. The maximum crystal size reported is about 3 by 2 by 2 inches, and the habit is generally short to moderately elongate prismatic.

Pollucite $(Cs,Na)_2(Al_2Si_4)O_{12}\cdot xH_2O$

Pollucite was sought within the Himalaya dike system by the General Electric Company during the 1920's. The mineral ordinarily is difficult to identify because its appearance is similar to that of feldspar. However, the density is significantly greater, and the vitreous luster is characteristic. Pollucite is the only silicate in which cesium is a major element, and the material from the dike system is as rich in Cs as any reported in the world. It occurs within the pocket zone as masses associated with pink tourmaline and lepidolite. Some of the masses are as much as several inches in maximum dimension, and are irregular in shape. The mineral is colorless to milky white.

Zircon $(Zr,Hf)SiO_4$

Zircon and uraniferous zircon have been found in sparse amounts from the dike system. The color ranges from a dark brown (U-bearing) to a light buff-orange-tan (non U-bearing), and radiation haloes are present around grains that contain significant amounts of U. The crystals are euhedral, forming stubby pyramids, and are associated with other pocket zone species. Rarely are they more than 0.5 inch in maximum dimension. The zircon is fluorescent orange or yellow-orange in ultraviolet light.

Monazite $(La,Ce,Nd)PO_4$

Monazite, like zircon, is a rare mineral from the pocket zone of the dike system. It typically occurs as euhedral crystals with tabular habit as much as 0.5 inch in maximum dimension. The color ranges from dark mahogany-red to chartreuse-green and greenish brown, and reflects extreme compositional zonation and inhomogeneity.

Clays

By far the most abundant clay mineral from the dike system is montmorillonite, $Ca_{0.33}(Al,Mg)_2\ Si_4O_{10}(OH)_2\cdot xH_2O$. It occurs chiefly within pockets (Fig. 17), in places associated with sparse kaolinite. Some pockets contain only white to pink clay that is chiefly montmorillonite, whereas others also contain deep red-brown, sticky clay that clearly reflects transfer of materials from the host-rock norite by surface waters. Among the montmorillonites examined, only Ca-Mg varieties have been found.

Topaz $Al_2SiO_4(F,OH)_2$

Topaz appears to be a rare pocket zone mineral apparently associated only with pink tourmaline, lepidolite, quartz and cleavelandite. It has been found in cellular to cavernous aggregates as well as isolated crystals that are perched on larger individuals of elbaite, potash feldspar and cleavelandite. The crystals are as large as 3 inches in maximum dimension and are colorless to very pale blue, distinctly paler than much of the topaz from other pegmatites in San Diego County. Best developed are the prism, base, and dome faces, and pyramidal faces also occur at the ends of crystals that project into cavities (Jahns and Hanley, 1955).

Beyerite $(Ca,Pb)Bi_2(CO_3)_2O_2$

Beyerite, a rare calcium-lead-bismuth carbonate, has not previously been reported from the Himalaya dike system. It occurs intimately mixed with montmorillonite, with or without an as yet unidentified Ca-V phosphate (hydrated?) within the pocket zone. It also can be found as isolated masses, in places associated with bismuth-bearing stibiotantalite, rynersonite, and fersmite. It is invariably a fine-grained, earthy powder with a maximum grain size of about 10 micrometres. The color ranges from yellow to greenish yellow.

Spinel

The spinel group appears to be represented in the dike system only by gahnite, $ZnAl_2O_4$, which occurs sparsely within the layered pegmatitic aplite rocks. The grains range in diameter from less than 0.01 inch to slightly more than 0.1 inch, and are a characteristic leek-green color. Microprobe analyses indicate the presence of major amounts of Fe (about 7% FeO) along with the Zn. Grains of gahnite are euhedral and have octahedral form.

Todorokite

This mineral, a rare hydrous manganese oxide with the general formula $(Mn^{+2}, x)(Mn^{+4})_3O_7\cdot 2\text{-}xH_2O$, has not previously been reported from granitic pegmatites. It is found chiefly in manganese and manganese-base metal ore deposits. Within the Himalaya dike system it occurs as a late-stage alteration product of pocket minerals, chiefly as a powdery coating on quartz,

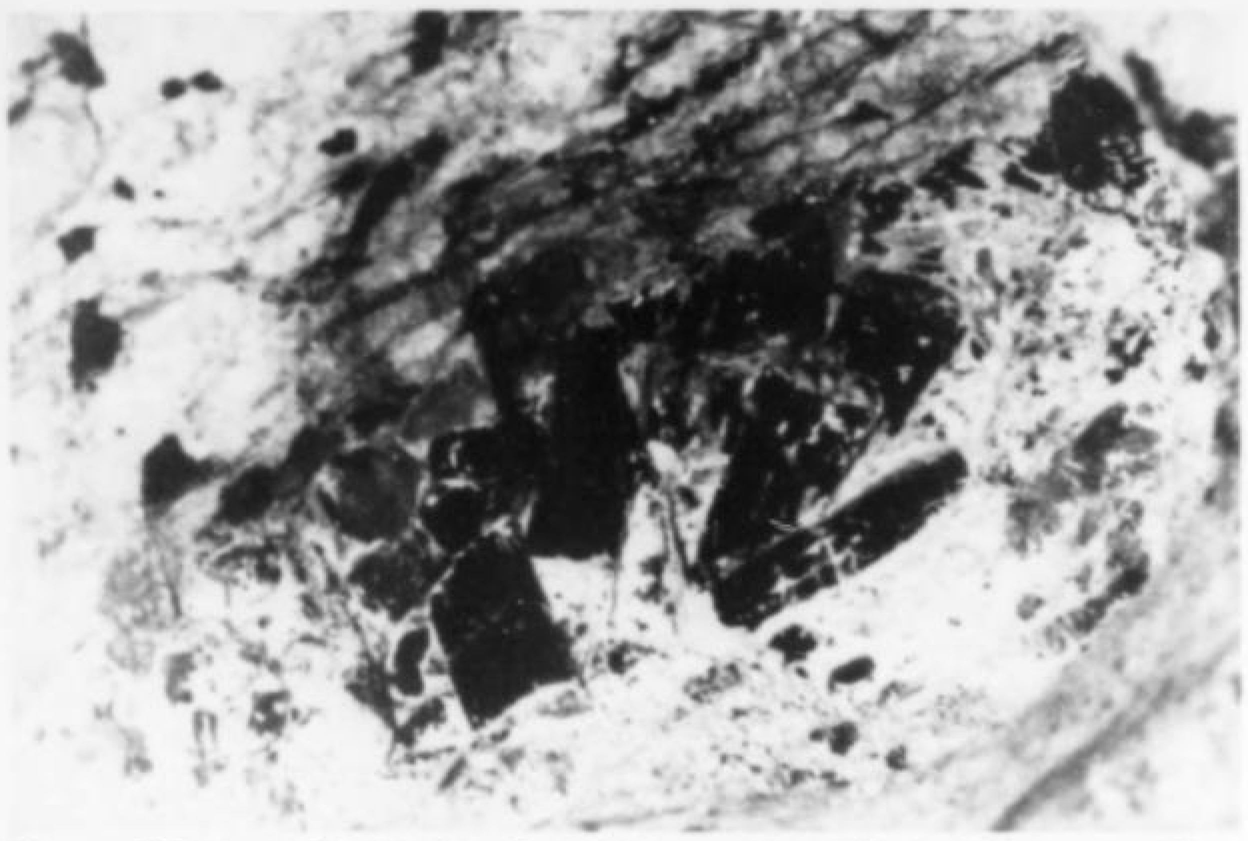


Figure 17. **A pocket in the San Diego mine filled with tourmaline imbedded in pocket clay.**

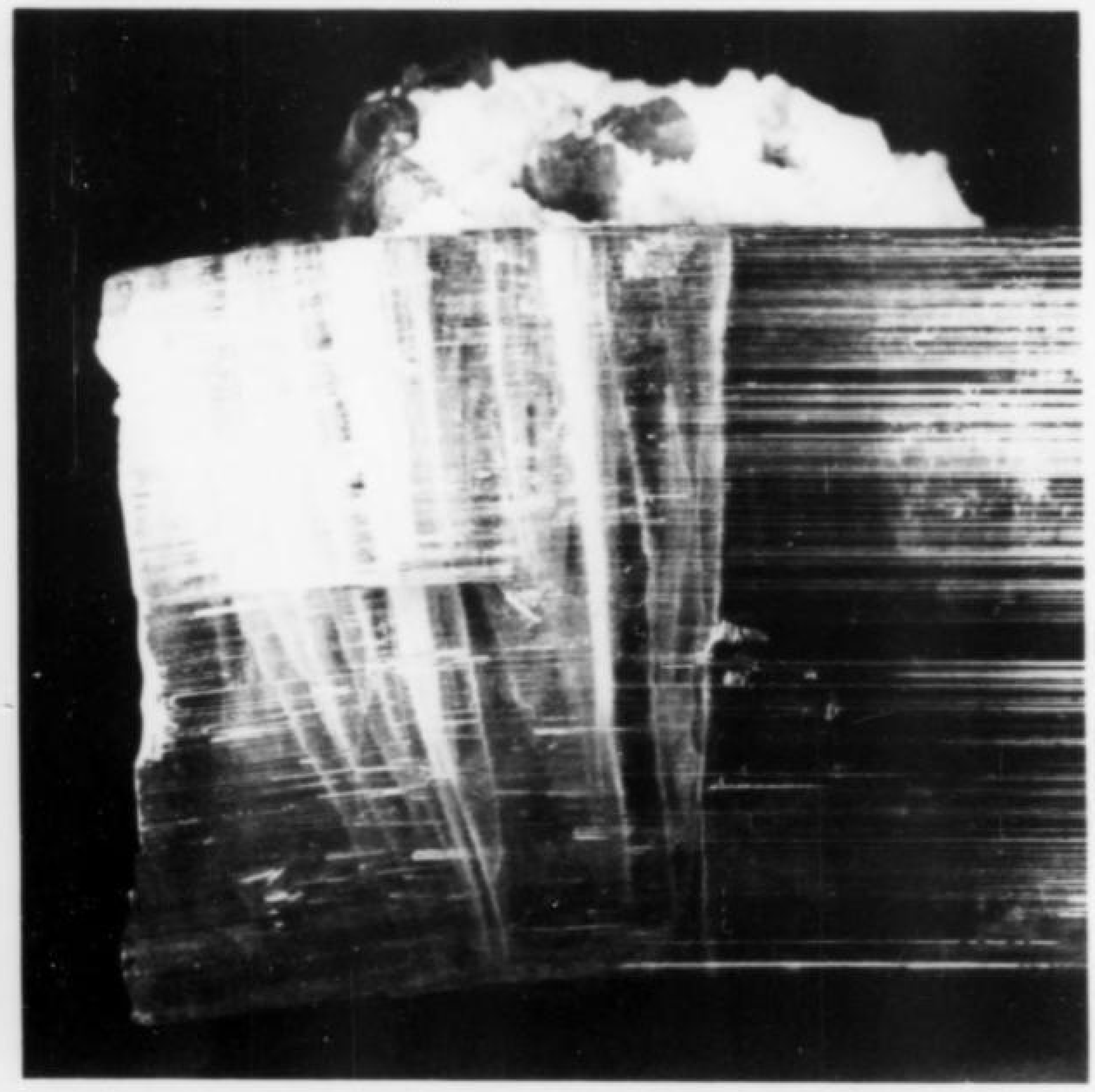
cleavelandite, tourmaline, and micas, and may be elsewhere as well. The color is black, typical of manganese oxides.

Zeolites

Zeolite-group minerals are common within the dike system, and particularly within pocket pegmatite. They fill fractures in other minerals, occur as coatings and alteration rinds, and also form isolated masses. They are most commonly associated with late-stage pocket minerals such as cleavelandite, pollucite, clays and micas.

Stilbite, $NaCa_2(Al_5Si_{13})O_{36}$-$14H_2O$, laumontite-leonhardite, $Ca(Al_2Si_4)O_{12}$-$4H_2O - Ca(Al_2Si_4)O_{12}$-$4$-$xH_2O$, thomsonite, $NaCa_2(Al_5Si_5)O_{20}$-$6H_2O$, and heulandite, $(Na,Ca)_{4-6}Al_6(Al,Si)_4Si_{26}O_{72}$-$24H_2O$, have been identified. The first two are most abundant. Stilbite forms stoutly tabular to elongate crystals as much as 0.5 inch length. Many occur singly, but more commonly they are found as radial clumps and mesh-like aggregates. Laumontite is present as slender, white crystals of columnar habit, typically in rosettes and fan-shaped groups as much as 0.5 inch in length. Heulandite and thomsonite are similar in appearance to laumontite.

Figure 18. (below) **Tourmaline (elbaite) from the Himalaya mine. The crystal is 3.2 cm thick, pink on the surface and green in the interior. The specimen has been bent by natural forces and the cracks rehealed by white tourmaline. Smithsonian specimen, NMNH# C3253-2. Photo by Wendell Wilson.**



Bavenite $Ca_4BeAl_2Si_9O_{24}(OH)_2$

Bavenite is a rare beryllium-calcium aluminosilicate reported from the Himalaya mine by Schaller and Fairchild (1932). It is a scarce but by no means rare constituent within the pocket zone, where it is characteristically associated with beryl as an alteration product. Several excellent pseudomorphs of bavenite after beryl have been observed. It ordinarily occurs as sheaflike aggregates of colorless to white fibrous crystals as much as several inches long, and as more or less earthy appearing anhedral masses as much as 5 inches across. The mineral is white but is rarely colorless as well. Crystal habit is elongate prismatic.

Thorogummite $Th(SiO_4)_{1-x}(OH)_{4x}$

Thorogummite has been identified from the pocket pegmatite zone, where it occurs as a fine-grained tan to buff powder pseudomorphous after an unknown mineral or minerals. The primary mineral is believed to have been thorite. Radiation damage characteristically is present in adjacent parts of associated minerals, among which are quartz, pink tourmaline, cleavelandite, and apatite. Some masses are as much as 0.2 inches across.

Cassiterite SnO_2

Cassiterite occurs within the graphic pegmatite and pocket pegmatite as euhedral pyramidal crystals an inch or more across (Fig. 21). The mineral is deep golden to reddish brown or black, and it is lustrous on both crystal and broken surfaces (submetallic). It occurs chiefly with albite, muscovite, blue-green tourmaline, spessartine, and quartz, and also in lesser amounts with very late-stage pocket minerals. Only minor percentages of Fe, Ti, Ta and Si are present as contaminants.

Stokesite $CaSnSi_3O_9 \cdot 2H_2O$

Of all the minerals examined from the Himalaya dike system during this study, stokesite is probably the rarest. The mineral, not previously reported from California, occurs as an alteration

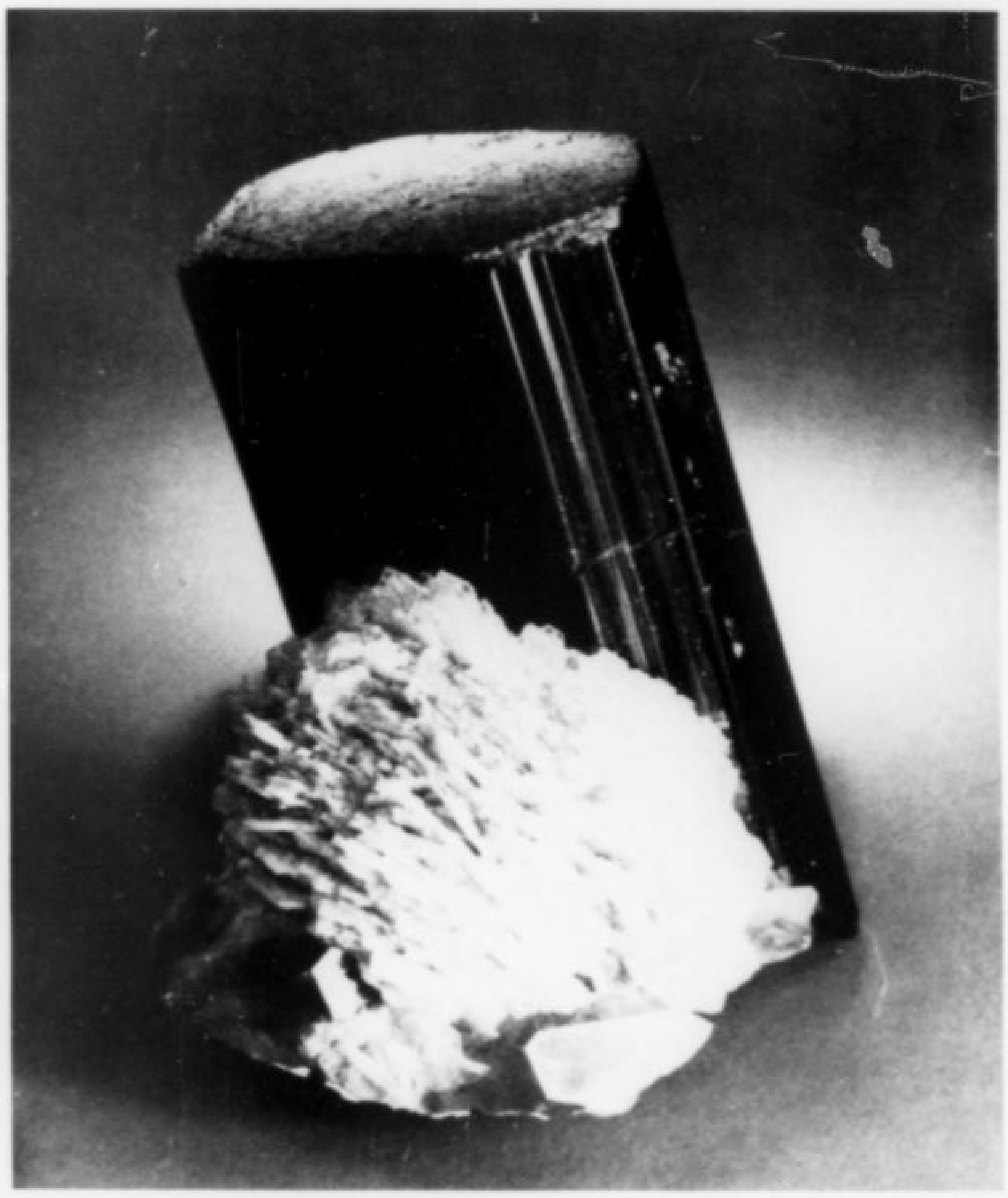


Figure 19. (above) **An apparently black crystal of tourmaline which is a very dark green on thin edges, associated with albite and quartz, from the Himalaya mine. The specimen is 4.5 cm tall, and is in the Smithsonian collection; NMNH# 123534. Photo by Wendell Wilson.**

product of cassiterite. All grains encountered have been less than 0.05 inch in maximum dimension. X-ray studies and microprobe analyses have confirmed the symmetry and chemistry of the mineral.

Other minerals

Herderite, $CaBePO_4(F,OH)$, and hambergite, $Be_2(BO_3)(OH)$, also have been reported from the pocket zone of the Himalaya dike system. Samples of both species were provided by J. F. Scripps for confirmation of their identity. Both are low-temperature secondary minerals. Spodumene, $LiAlSi_2O_6$, also has been reported in small amounts from the Himalaya mine, but it was not identified during this study. An as yet unidentified Ca-V phosphate is commonly associated with thorogummite.

MINERAL PARAGENESIS AND SUMMARY

Figure 22 is a paragenetic diagram for minerals from the Himalaya dike system. It can be seen that there is a definite sequence and association for these constituents.

The following model is proposed for crystallization of the Himalaya dike system, based on the information presented here and from Foord (1976). After emplacement of an aqueous granitic magma, initial crystallization yielded fine-grained, nonlayered pegmatitic aplite along the footwall of the lower dike. Extremely rapid vertical differentiation yielded Na-rich lower portions and K-rich, volatile-rich upper portions. With declining temperature and continued crystallization, minor fluctuations in pressure-temperature-composition conditions caused formation of layered aplite and pegmatitic aplite contemporaneously, with hangingwall graphic to massive pegmatite. As the residual fluids were progressively enriched in hyperfusible (any substance capable of lowering the melting ranges in end-stage magmatic fluids) constituents, including volatiles, the content of these constituents reached a level where exsolution of a discrete vapor phase resulted. Pocket zone pegmatite crystallized in the presence of this aqueous phase and, depending on the local abundance of iron, either pink or green tourmaline was formed. Isolated and/or semi-isolated cavities (pockets) ultimately were left in this zone, and crystallization continued within them from the vapor phase. If the vapor pressure of the contained aqueous phase greatly exceeded that of the confining pressure on the pockets, they ruptured with variable degrees of violence. The temporary supercooling resulting from the sudden pressure decrease, as well as the pressure decrease itself, resulted in thermal shock which was responsible for the shattering so evident in pocket minerals. However, if a pocket did not rupture, then hydrothermal alteration at lower pressure and temperature resulted in destruction or partial destruction of the pocket contents. We have here a case of a cruel paradox, if a pocket did not rupture at least once, there were no gem minerals formed, yet rupture invariably induced close fracturing of contained phases. Growth of minerals after rupture was of excellent quality if only one such episode of major rupture occurred. Subsequent rupturing events also resulted in crystals showing the results of thermal shock. The internal pocket pressure must be reduced, through one or more rupturing episodes, below some critical value for the primary minerals to survive unaltered. All pockets, however, contain some secondary alteration minerals, which invariably formed during the later stages of cooling of the dike system. The pocket clays were the last to form and may have been formed from pre-existing primary minerals as well as introduced from outside the dike system.

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The author wishes to acknowledge the excellent supervision and support provided by Richard H. Jahns of Stanford University. His direction as principal thesis advisor, from which this paper was drawn, has been invaluable. Without the coopera-

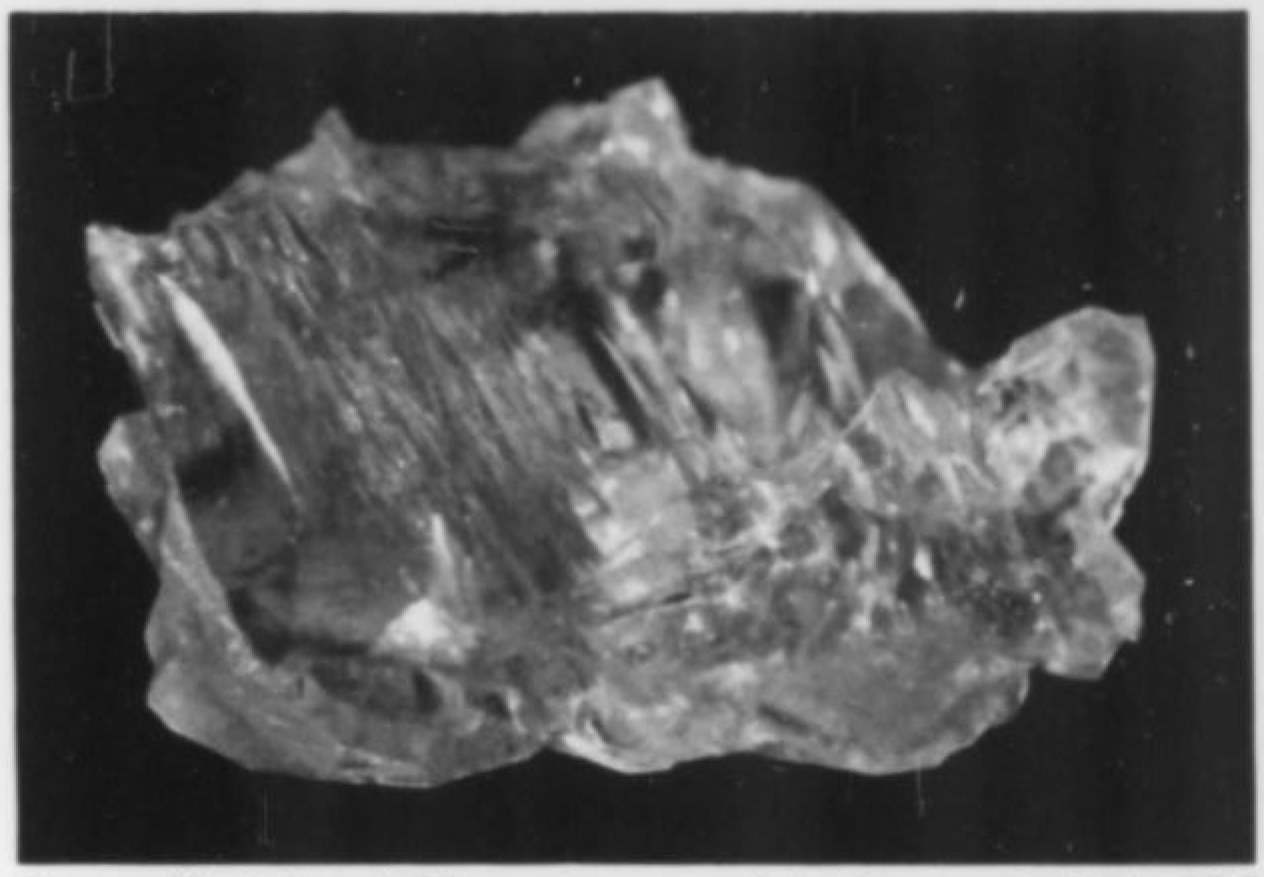

Figure 20. (above) **Morganite crystal (pale peach-pink), 99.3 grams, from the Himalaya mine. See also the color photo of a Himalaya morganite in William Larson's article elsewhere in this issue. Linley K. Hall collection.**

Figure 21. (below) **Cassiterite (black) with albite (white) on tourmaline (green) from the Himalaya mine. The tourmaline crystal is ~ 5 cm tall. William Larson collection; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

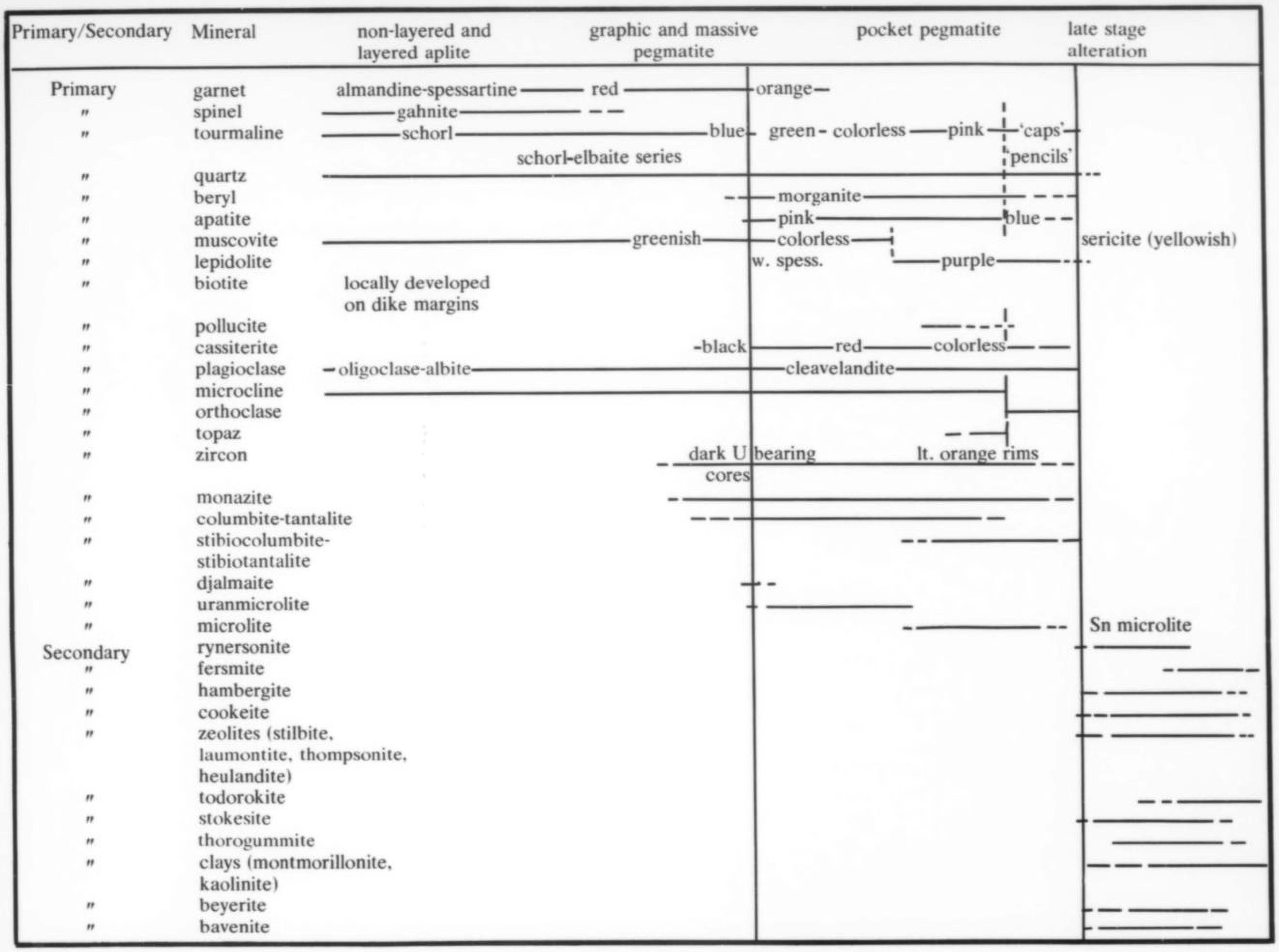

Figure 22. **Postulated paragenetic sequence diagram for minerals of the Himalaya dike system.**

tion and assistance of Eugene B. Rynerson, owner and operator of the San Diego tourmaline mine, this research would not have been possible. Several residents of San Diego County kindly permitted examination of their private mineral collections and loaned crucial specimens for scientific study. Most helpful in this sense were Linley K. Hall, Lyn Johnson, William Larson, Josephine Scripps, and William Woynar. Thanks are due to Richard H. Jahns, Eugene B. Rynerson, and Linley K. Hall for reviewing this paper.

NOTE

Fine specimens of minerals from the Himalaya dike system are in the collections of the following museums and private collectors:

1. Smithsonian Institution (National Museum of Natural History), Washington D.C.
2. California Institute of Technology, Pasadena, California.
3. San Diego County Museum, San Diego, California.
4. Josephine F. Scripps, San Luis Rey, California.
5. Himalaya Mining Corporation, San Diego, California.
6. John Sinkankas, San Diego, California.

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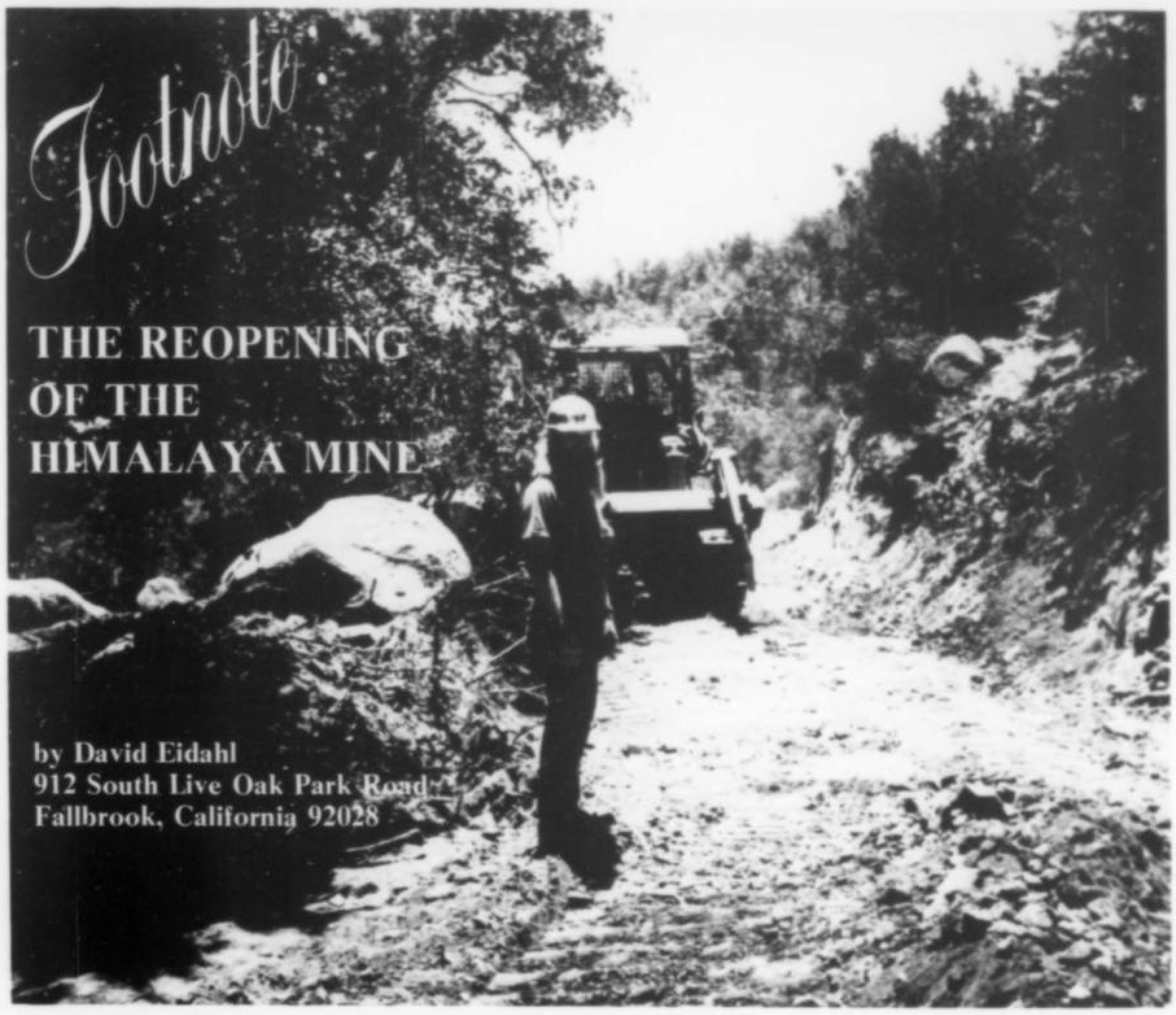

Footnote:

THE REOPENING OF THE HIMALAYA MINE

by David Eidahl
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Relatively little work has been done at the Himalaya mine since 1964. Pala Properties International recently acquired the lease to the mine, and has reopened the deposit.

Over a year of negotiations and research preceded the reopening. The area was studied and surveyed, and it was finally decided to begin operations not at the main site of the old workings but directly over the mountain on the east side. Here the Himalaya dike resurfaces after passing through the mountain. A short adit had been driven into the east side by Ralph Potter, who mined the pegmatite full-time until 1964, but little else had been done there until July 7, 1977, when Ed Swoboda, his son Bryan, Dave Wilber, John McLean, Ralph Potter and I met at the Himalaya mine to break ground for the new operations.

After a long, early-morning ride up the mountain, with occasional stops to open and close gates, we reached the original workings on the west side of the mountain. The old main haulage tunnel was completely collapsed; a small building Ralph had once erected in which to sort tourmaline still stood. Even the wooden sign bearing the mine name still swung from a rusty hinge. Walking around the dump for awhile, Dave reminisced about visiting the mine in the days when it was swamped with people.

But this was not where the new work would begin, so we climbed back into the pickup truck, drove to the top of the mountain, and parked. We descended on foot down a path lined with poison oak to the east side workings. Reaching the old pad, we looked about for the old adit. It was caved in and overgrown with brush.

Ed and his son had camped overnight at the mine, and came down the hill to greet us, followed by Ralph Potter. While we all waited for the D-8 Caterpiller to arrive, Ralph regaled us with stories of the old days.

At 7:30 AM a loud roar was heard from the canyon below; the Caterpiller had arrived and was making its way up the steep mountain. At first it looked like a small toy, spitting out bursts of black diesel smoke, but as it got closer it could be seen to fill the whole road: an enormous machine indeed. Under the direction of Ed and John, the Caterpiller carved out a new, wider road to the east side workings with skillful ease.

There was an air of excitement, a feeling that something significant and promising was happening. After all, the Himalaya mine was already a famous locality, having produced more tourmaline than any other locality in the world, over 80 *tons*... so far. Perhaps the reopening would bring more treasures. Cameras clicked, Dave posed smiling in front of the Caterpiller's 10-foot blade. Ed carried a portable tape recorder, capturing the sounds of the moment.

Once at the mine site the Caterpiller began cutting into the hillside. Large boulders, some up to 6 feet, were worked out and pushed over the edge of the dump. The entrance to the old tunnel had collapsed, but as the Caterpiller cut back the ground we could again see the outline of the old tunnel.

We could see something else as well...little reflections on the ground. Tourmaline! Ed rushed in to gather up the crystals from the path of the Cat. A small pocket had been cut into: an appropriate way to christen the first day of work! The crystals ranged in size up to ½ by 1 inch, and were green with black tips, a type referred to by some as coming from a "house pocket."

By the end of the day the original 20 by 40-foot pad had been enlarged to 40 by 150 feet. A couple of days later John cleaned out the old tunnel entrance to expose the pegmatite dike. Since then the tunnel has been shored and more tourmaline has been discovered.

It remains to be seen whether the Himalaya mine will again yield tourmaline of the fine quality produced in the old days (see the color photos in the preceding article) but with such a large section of the pegmatite dike lying untouched between the old and new workings on opposite sides of the mountain, we have high hopes.

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300645. A GEOLOGIST'S VIEW OF CAPE COD, A.M. Strahler. Clothbound. Publisher's Price $2.95, Our Price $2.75

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300535. AN INTRODUCTION TO THE PRACTICAL STUDY OF CRYSTALS, MINERALS & ROCKS, Cox, Price & Harte. 1975 revised edition. Paperbound. Publisher's Price $10.75, Our Price $10.00

300533. AN INTRODUCTION TO THE ROCK FORMING MINERALS, Deer, Zussman & Howie. 1973, 528 pp. Paperbound. Publisher's Price $12.50, Our Price $11.65

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MINERALOGY OF THE CHAMPION MINE
WHITE MOUNTAINS, CALIFORNIA

by William S. Wise
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Santa Barbara, California 93106

The bold, bleached outcrop of quartzite at the 2800 m level on the west front of the White Mountains of eastern California is visible for tens of miles. For mineral collectors it marks a locality* well known for its large rutile crystals and rare phosphate minerals.

The locality is known mainly because it was mined by the Champion Sillimanite Company for andalusite during the 1920's and 30's. The mining operation was supervised during most of this time by C. D. Woodhouse (see Bancroft, 1976), who was an excellent mining geologist and a dedicated, perceptive mineralogist. This description of the mineralogy and geology of the deposit is dedicated to his memory, for without his generosity and encouragement my research into the minerals and paragenesis would not have been carried out.

The deposit was discovered in 1919 by J. A. Jeffery, then president of the Champion Porcelain Company. Using descriptions of occurrences of andalusite in the White Mountains (Knopf, 1917) he found rich masses of andalusite-bearing rock in the near vertical cliff faces (Fig. 1 and 2). The difficulties encountered in the mining of ore from the hard, vertical faces were described by Woodhouse (1951). The ore was of sufficient value to be sorted and loaded into sacks at the mine. This part of the White Mountains is so steep that the ore had to be carried by mule 3½ miles and down 780 m to an area where it could be loaded into trucks.

With a few notable exceptions the minerals in the Champion mine and close vicinity are compounds of aluminum. The general assemblage is similar in many ways to that at Graves Mountain, Georgia (Hurst, 1959). Here I will describe some of the more interesting minerals and the geologic setting for the deposit, and then will offer an explanation for the origin of the entire assemblage.

GEOLOGY OF THE DEPOSIT

Recent mapping of the western front of the White Mountains by Crowder and Sheridan (1972) shows that all the localities in Figure 3 lie within the White Mountain fault zone. This zone has a width up to one mile and is composed of sheared and mixed blocks of metavolcanic and metasedimentary units of Permian to Jurassic age. In the northern part of the range the fault is cut by Cretaceous dikes of aplite and pegmatite (Crowder, Robinson, and Harris, 1972). The part of the fault zone in which the Champion mine is located is believed to be composed of a metamorphosed rhyolite. Elsewhere along the fault zone these metarhyolites appear as muscovite-albite-quartz schists. The more mafic metavolcanic rocks form chlorite-chloritoid schists.

The Jurassic intrusion near the fault zone in the vicinity of the andalusite deposit is similar to those cut by the fault to the north and therefore is older than the formation of the deposit. However, an outcrop of Cretaceous granitic rocks is within 2 miles and may have a genetic connection with the andalusite.

MINERALOGY

Table 1 is a list of the major minerals that have been identified at the Champion mine, and Figure 3 shows the best collecting localities for these minerals. Much of the data presented here were obtained from specimens donated to the University of California, Santa Barbara, by C. D. Woodhouse, but frequent reference was also made to Lemmon (1937b) and Gross and Parwell (1968). The mineralogy descriptions will concentrate on two major parts of the area: the **orebody** (locality **A** in Fig. 3) and the **phosphate rock** (locality **B**, Fig. 3) formed along shear zones in andalusite-quartz rock.

Minerals of the ore body

Andalusite (Al_2SiO_5). Much of the andalusite occurs as coarse granular masses in the quartzite of the ore body. Crystals or clusters of crystals form columnar masses (Fig. 4). The andalusite is pale green or yellow-brown to white, but most crystals are coated with a thin layer of pyrophyllite or muscovite. The prismatic crystals, ranging from a few millimetres to 10 cm in length have simple {210} and {101} forms.

Some of the andalusite — most of that forming the columnar crystals projecting into cavities — has had some of the alumina leached away by late fluids. These prismatic crystals, such as in Figure 4, are partial pseudomorphs of quartz after andalusite. During the mining operation the specific gravity of the ore samples was periodically determined to eliminate this kind of

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*The mine has carried a number of names in the past. It is referred to in *Minerals of California* (Murdoch and Webb, 1966) variously as the Champion Sillimanite mine, Champion Sillimanite Incorporated mine, Champion Sillimanite Company Incorporated mine, and the Mono County mine of Champion Sillimanite Incorporated. Woodhouse (1951) was bothered by the fact that no sillimanite has ever been found at the locality, and followed the practice of company reports (of the Champion Sillimanite Company), calling it the Mono County Andalusite mine. Many labels in the Smithsonian give the locality simply as the Champion mine, and this name is in frequent use among collectors. I therefore propose that it be officially adopted.

Figure 1. (above) **A view of the Champion mine. The ore body was located in the cliff face of the highest outcrop. Most of this view is shown on map Figure 3.**

Figure 2. (below) **The mining operation in 1935. The string of pockets are mined out andalusite ore bodies, and illustrate the distribution of ore (Lemmon photo).**

material. Therefore specimens can still be found in the dump talus slopes.

Quartz (SiO_2). Quartz is certainly the most abundant mineral in the area, forming the bold outcrops. However, long prismatic crystals up to 10 cm were found lining the walls of vugs and fractures. They are commonly associated with tourmaline (schorl), pyrophyllite, muscovite, and woodhouseite (Fig. 5).

Corundum (Al_2O_3). Corundum is a scarce but persistent mineral in the ore body. It occurs most commonly as plates or irregular crystals included in andalusite masses. Clusters of crystals up to 15 cm were found during the mining operation. All of the corundum is deep blue. Lemmon (1937b) noted that the color was not evenly distributed but strongly concentrated in a few spots within a crystal. These spots are similar in size and distribution to the disseminated rutile in the deposit, strongly supporting the supposition that titanium causes the blue color.

Topaz ($Al_2SiO_4F_2$). Topaz is a common mineral, but almost never displays any crystal form at this locality. It is frequently overlooked in the ore because of its similar appearance to quartz. A few topaz crystals have been found in vugs in the andalusite body and in the Al-phosphate rock (see below).

Rutile (TiO_2). Occurring mostly as tiny crystals less than 1 mm across, rutile is disseminated throughout the entire area. The quartzite and andalusite ore are tinted pink from the tiny red grains, forming about 0.5% of the rock. As reported by Lemmon (1937b) and Gross and Parwell (1968) much larger crystals occur in two zones below the main quartz mass (see Fig. 3) and at a small claim a few hundred metres west of the map area of Figure 3. These large crystals occur in zones of particularly coarse-grained diaspore-pyrophyllite rocks, easily breaking free. Crystals range up to 6 cm (Fig. 6 and 7).

Generally the rutile forms crystals that are complexly twinned and are nearly equidimensional. They are deep red to red-brown with a submetallic luster. Figures 6 and 8 illustrate the simple untwinned tetragonal prism with various bipyramid forms. All of the crystals for which the twinning relations have been solved are twinned on (031) (Fig. 8), although eightlings have been reported (presumably twinned on (011)).

Diaspore (AlOOH). Diaspore forms white to yellow-brown blades and plates up to 3 cm in length. In the andalusite ore it occurs as sparse, thin plates. In localities such as near H in Figure 3 it forms massive bodies of interlocking plates associated with pyrophyllite and rutile. Very few crystals exhibiting faces have been found.

Pyrophyllite ($Al_4Si_4O_{10}(OH)_2$). This mineral is wide-spread throughout the area. It occurs as white to colorless plates, commonly in radiating clusters up to 1 cm in diameter. Small clusters or sheaves occur throughout the ore body, commonly as a late replacement of andalusite. Only where pyrophyllite forms radiating clusters is the distinction clear. Much of the pyrophyllite has formed as a reaction product from andalusite and water vapor. It can be thought of as an adjustment of the system to cooling temperatures.

Woodhouseite ($CaAl_3SO_4PO_4(OH)_6$). The White Mountain deposit is the only known locality for this member of the alunite group. First described by Lemmon (1937a), woodhouseite occurs in open cavities in quartz veins and alteration seams in the andalusite rock and quartzite. Crystals vary from clear and colorless to translucent and pale orange pseudo-cubic rhombohedra. Typical growths of the larger woodhouseite crystals are shown in Figures 10 and 11. In some cavities tiny crystals are perched on schorl fibers (Fig. 12). The common forms are shown in Figure 13.

Microprobe analyses (Wise, 1975b) of samples from many localities (A, F, and D. Fig. 3) reveal a complete solid solution series with **svanbergite**. Moreover, a few crystals have been found that contain Ba in amounts to 20 mole percent.

Because of its location in seams and vugs in andalusite ore and quartzite, woodhouseite is clearly a late-formed mineral. It formed from sulfate- and phosphate-bearing solutions reacting with andalusite or pyrophyllite.

Svanbergite ($SrAl_3SO_4PO_4(OH)_6$). Pale yellow to orange simple rhombohedral crystals up to 5 mm occur with fibers of blue-gray schorl in a quartz vein at locality H in Figure 3. Crystals found at the Moreau claim by A. Ordway contain an excess of phosphorus, indicating a partial solid solution series with goyazite (Wise, 1975b).

Phosphate Rock Minerals

The phosphate rock formed along two shear zones (locality B, Fig. 3) through andalusite-muscovite schist. It is composed chiefly of augelite, trolleite, strontian natroalunite, and topaz with minor rutile and quartz (Fig. 16). All of these minerals are clearly later than the formation of andalusite. The phosphate rock also contains small cavities containing even later phosphate minerals (Fig. 16).

Strontian natroalunite ($(Na,K,Sr)Al_3(SO_4,PO_4)_2(OH)_6$ This compositional variety of natroalunite occurs abundantly in quartz veins and with augelite and trolleite in the area around locality B (Fig. 3). It most commonly forms granular, pink to pale brown masses, but also forms rhombohedra modified by basal faces. Although the compositions are variable, an average can be represented by 45% natroalunite, 30% alunite, and 25% svanbergite (Wise, 1975b).

Augelite ($Al_2PO_4(OH)_3$). This mineral occurs rarely as fracture coatings and miarolitic cavity fillings in the andalusite bodies and in the massive phosphate rock of locality B (Fig. 3). The crystals from the fractures and cavities are commonly euhedral, colorless, and transparent (Fig. 14). Lemmon (1935) described the crystal forms of this material, and Figure 15 is a drawing of the common tabular form. Some of the early found crystals are nearly 2.5 cm across, while those with the best crystal form are about 1 cm.

In the phosphate rock the augelite is anhedral and is recognized by its white color and prominent basal cleavage. Some of these crystals reach 10 cm, and commonly include smaller grains of rutile, trolleite, and topaz.

Experimental work has shown that augelite can form readily from a reaction of andalusite and phosphoric acid. Moreover, augelite is not stable at temperatures above 500°C (Wise and Loh, 1976).

Trolleite ($Al_4(PO_4)_3(OH)_3$). Trolleite is a very rare mineral, having been reported from only three localities in the world. Gross and Parwell (1968) were the first to note its existence in the phosphate rock in the White Mountains. It forms pale blue to pale blue-green masses intergrown with augelite and topaz. Crudely formed crystals have been found only in a few cavities in the phosphate rock.

Trolleite is easily synthesized, and has a stability range at somewhat lower temperatures than does augelite (Fig. 17).

Lazulite $[(Mg,Fe)Al_2(PO_4)_2(OH)_2]$. The deep blue color of this mineral makes it the most striking of the deposit. It occurs in veinlets cutting the ore body, widely disseminated in the phosphate rock, and in vein quartz (locality H. Fig. 3). Well-formed crystals are rare; those that have been found have the simple pyramid forms, typical of the mineral at Graves Mountain, Georgia. Masses up to 10 cm across occur in quartz veins near locality H (Fig. 3).

Samples from various locations (A, B, and H) were analyzed with an electron microprobe. All except those associated with svanbergite and schorl have $Mg > Fe$, and are lazulite. The

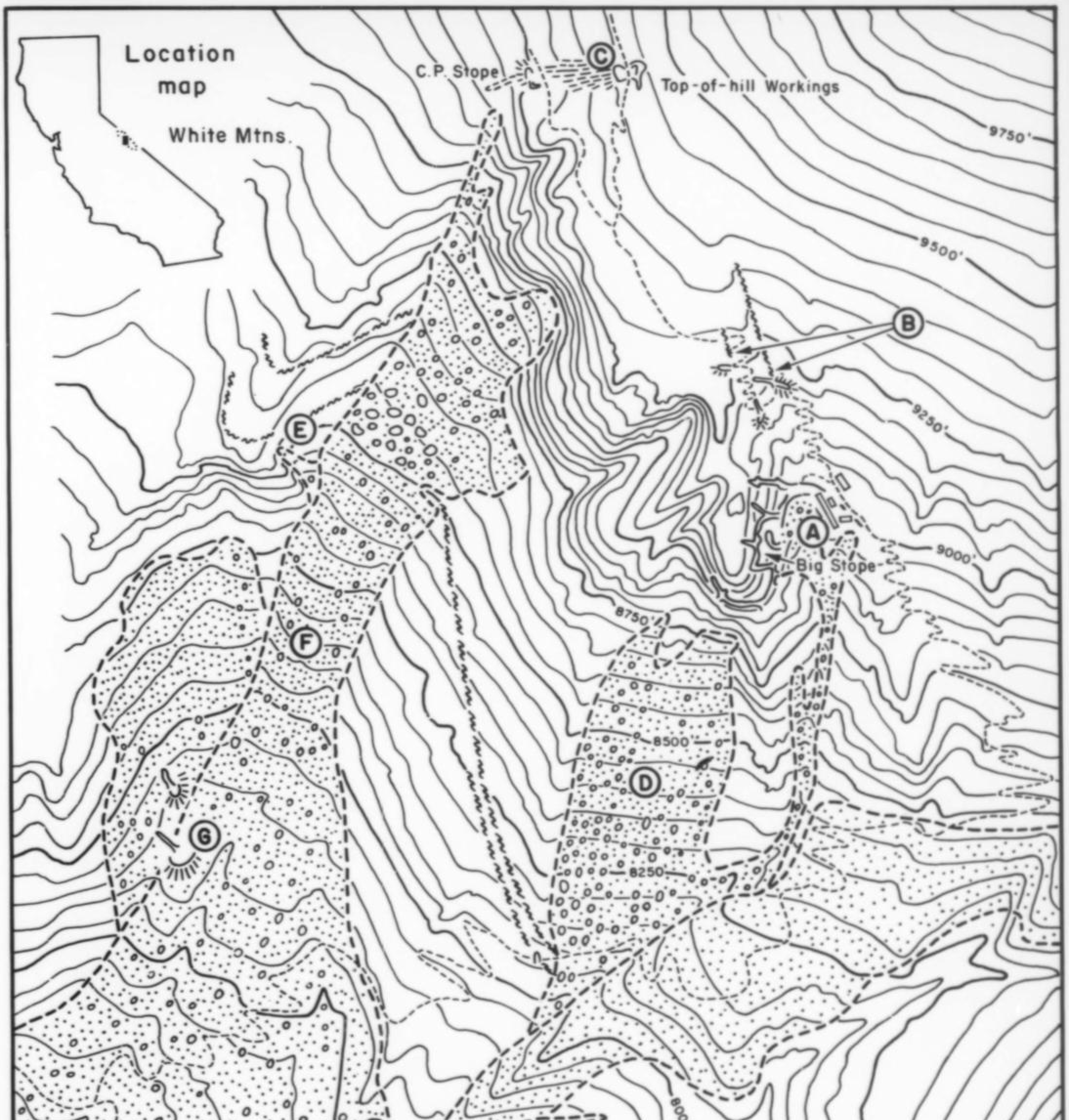


Figure 3. **Collecting localities at the Champion mine.**

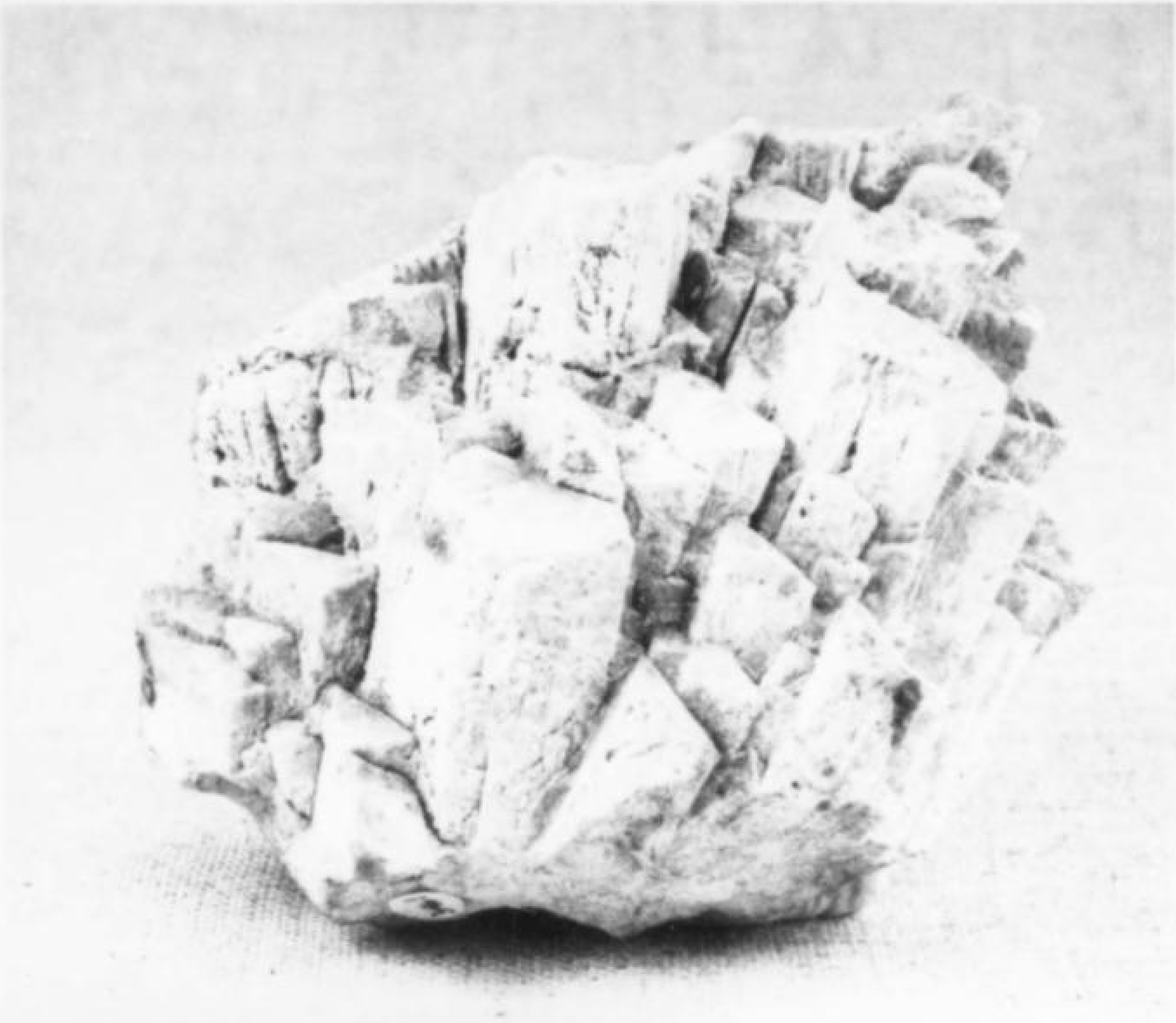


Figure 4. (above left) **A cluster of andalusite crystals with simple prism and dome faces. The crystals are about 3 cm long.**

Figure 5. (below left) **A quartz crystal 4.5 cm long with inclusions of pyrophyllite and rutile.**

Figure 6. (above right) **A complexly twinned rutile crystal in pyrophyllite. The crystal is 5.5 cm in the longest dimension.**

Figure 7. (below right) **A single crystal of rutile (3.5 cm high). Compare with Figure 8 to identify the crystal forms present.**

material with the svanbergite is then **scorzalite.**

Other minerals:

Many cavities in the phosphate rock are partially lined with pale orange **apatite** crystals (see Fig. 16). Forming even later is **viséite** in the form of white, earthy aggregates.

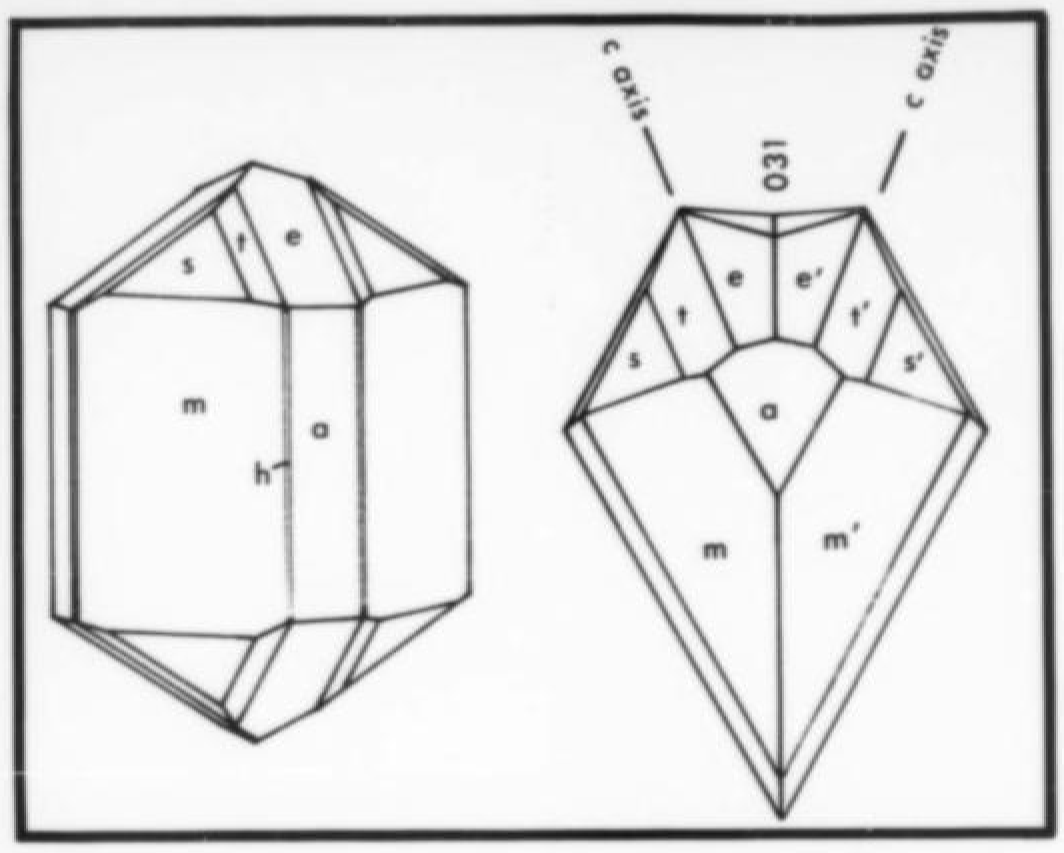
The experimental work by Wise and Loh (1976) indicates that berlinite ($AlPO_4$) is to be expected in this mineral environment. However, since berlinite is very nearly identical with quartz in its physical properties, it has not yet been recognized at this locality.

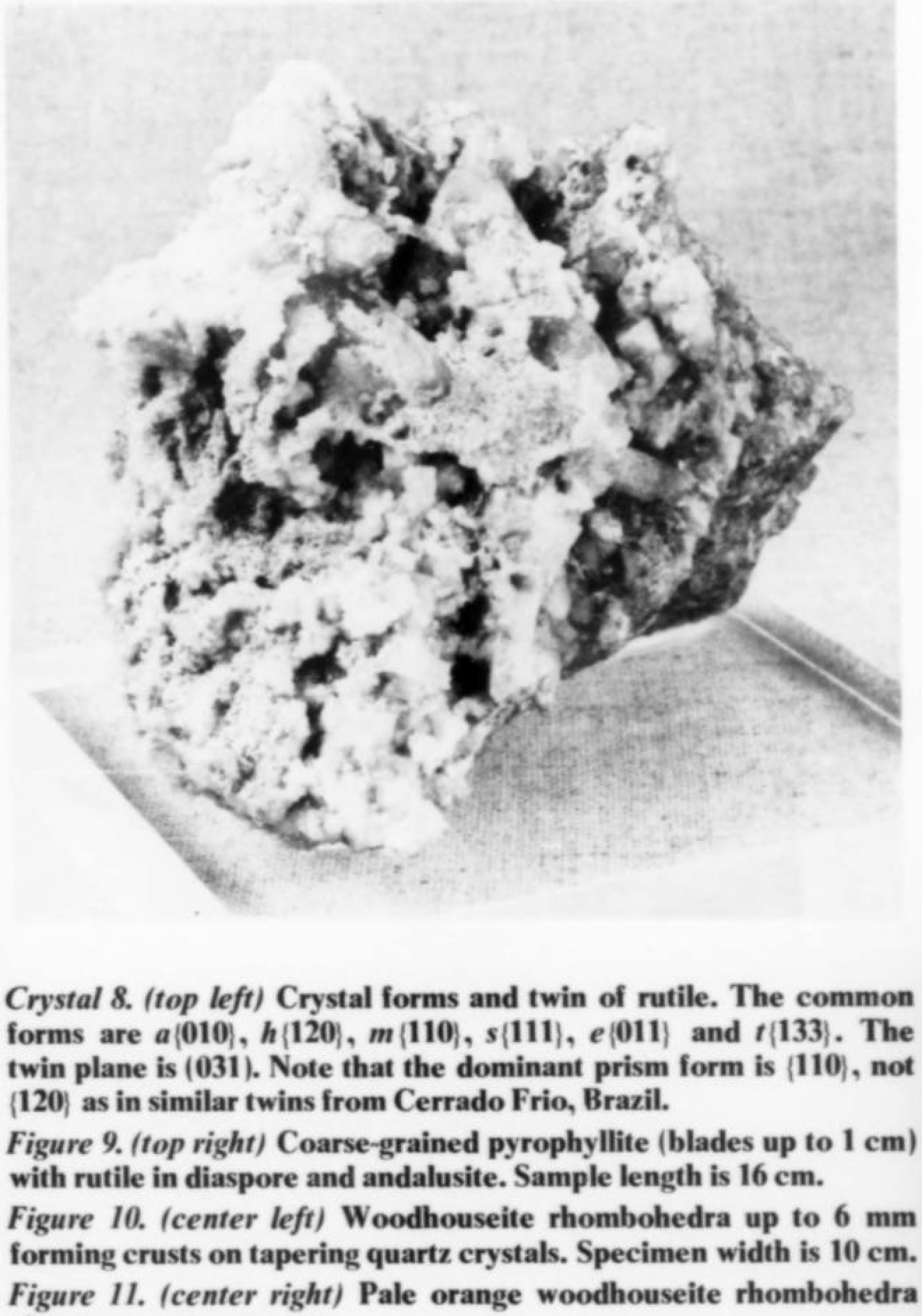
Table 1 lists other minerals that occur largely as weathering products. Most are found in seams and on joint surfaces.

ORIGIN OF THE DEPOSIT

For earlier workers the mass of quartzite, large pods of andalusite or pyrophyllite, finely disseminated rutile, local concentration of diaspore, corundum, topaz, and Al-phosphates have defied easy explanation. Recent experimental work (Wise, 1975a, and Wise and Loh, 1976) provides the basis of an hypothesis that makes explanation of the observed features easier. First, the coexisting minerals provide the temperature-pressure range within which the deposit formed regardless of the mechanism that brought these elements together. In Figure 17 we can see that the andalusite could have formed at the highest temperatures (between 400 to 600°C), while the augelite is limited to temperatures lower than 475°C. The phosphate rock could not have formed at temperatures much above 400°C. The pyrophyllite-diaspore rich zones probably crystallized below 350°C.

Kerr (1932) suggested that the andalusite formed from the metamorphism of aluminous volcanic material or sediment interlayered with trachytic flows. Gaseous and aqueous solutions were thought to have caused the crystallization of topaz and schorl and, as temperatures decreased, pyrophyllite and diaspore. Lemmon (1937b, p. 59) argued that the andalusite formed by *"metamorphism of a highly aluminous quartzite at considerable depth..."* with the addition of boric, sulfuric, hydrofluoric,





Crystal 8. (top left) **Crystal forms and twin of rutile. The common forms are $a\{010\}$, $h\{120\}$, $m\{110\}$, $s\{111\}$, $e\{011\}$ and $t\{133\}$. The twin plane is (031). Note that the dominant prism form is {110}, not {120} as in similar twins from Cerrado Frio, Brazil.**

Figure 9. (top right) **Coarse-grained pyrophyllite (blades up to 1 cm) with rutile in diaspore and andalusite. Sample length is 16 cm.**

Figure 10. (center left) **Woodhouseite rhombohedra up to 6 mm forming crusts on tapering quartz crystals. Specimen width is 10 cm.**

Figure 11. (center right) **Pale orange woodhouseite rhombohedra (9 mm across) on quartz.**

Figure 12. (bottom right) **Microcrystals of woodhouseite on tourmaline fibers with quartz crystals in a vug in quartzite. Width of view, 1 cm.**

Table 1. Minerals of the Champion mine.

Mineral	Abundance and form *	Illustrated in figure	Best collecting locations (Fig. 3)	Comments
***high temperature minerals* (400-600°C)**				
Quartz	*X, M*	5	A	Best crystals are in partially filled fractures and vugs
Corundum	(x), (m)		A	Occurs as deep blue plates (in andalusite)
Andalusite	m, x	4	A and C (also D, E)	Many crystals have been partially leached of the alumina, and are now quartz and andalusite.
Hematite, Ilmenite	m		B and elsewhere	In schists
Pyrite	*M*, x		A and H	Many pseudomorphs, goethite after pyrite
Muscovite	X, m		A and elsewhere	In veinlets with tourmaline and quartz
Topaz	M	16	A and B	Occurs in quartzite and trolleite-augelite rock
***moderate temperature minerals* (300-400°C)**				
Schorl	x, (m)	12	A, H, and in country rocks	Occurs as fine, hair-like fibers in veinlets, also as porphyroblasts
Trolleite	m	16	B	Massive with augelite, lazulite and topaz
Rutile	*M*,x	6, 7, and 8	E, G, and elsewhere	Large crystals at E and G in pyrophyllite, occurs as small grains throughout entire area
Diaspore	M		H, near D, E	Massive with lazulite and pyrophyllite or muscovite
Pyrophyllite	M,X	9	G and elsewhere all localities	Radiating clusters of plates up to 12 mm near G
Lazulite-Scorzalite series	M		All localities	Masses from all occurrences are dark blue, in quartz veins and quartz or phosphate rocks
Augelite	m, (x)	14, 15, 16	B (massive)	Occurs as massive crystals up to 13 cm with trolleite-lazulite-topaz
			A (crystals)	Crystals in veinlets with tourmaline, quartz, and muscovite
Woodhouseite	x	10 to 13	A (original loc.) and F and D in talus	Occurs as 2 to 6 mm crystals in fracture fillings
Svanbergite	(x)		H (and D)	Occurs with quartz in veinlets and similar to woodhouseite
Strontian natro-alunite	M, (x)		All localities	In veinlets with quartz
***low temperature minerals* (lower than 300°C) forming later than those above**				
Barite	(x)		A, B, F, G	In fractures
Apatite group	(x)	16	B	In cavities replacing augelite
Jarosite-natro-jarosite series	(x)		F and G, others	Late fracture fillings
Viséite	(m)	16	B	In cavities with apatite
Strengite	(m)		A, B	
Variscite	(m)			

Other minerals occurring mostly as low temperature reaction products are: limonite, sulfur, calcite, cacoxenite, opal, todorokite, chloropal, alunogen, and alumino-copiapite.

* M = massive, X = crystals; *X, M* = abundant, X, M = common, x, m = rare, (x), (m) = very rare

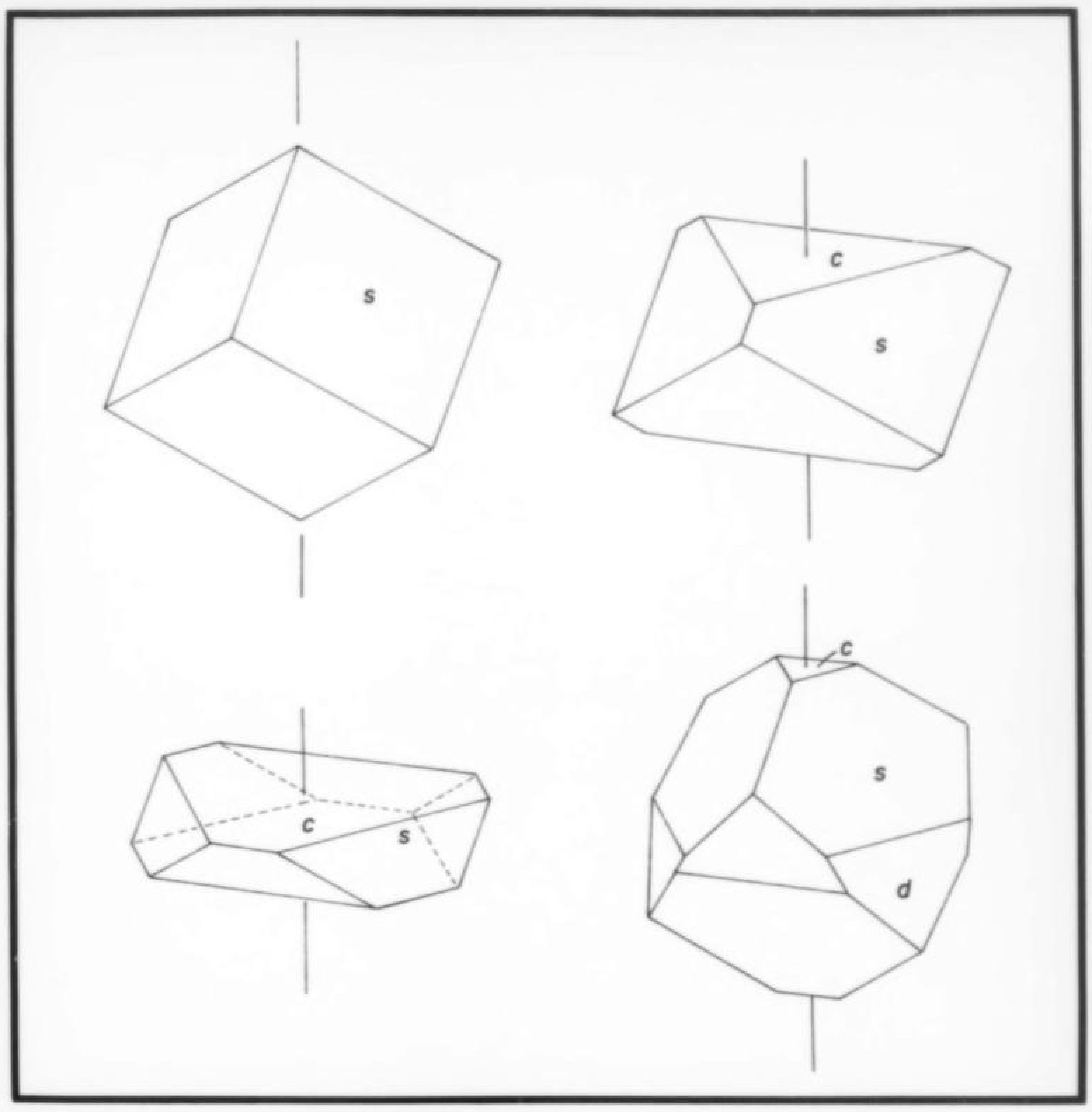
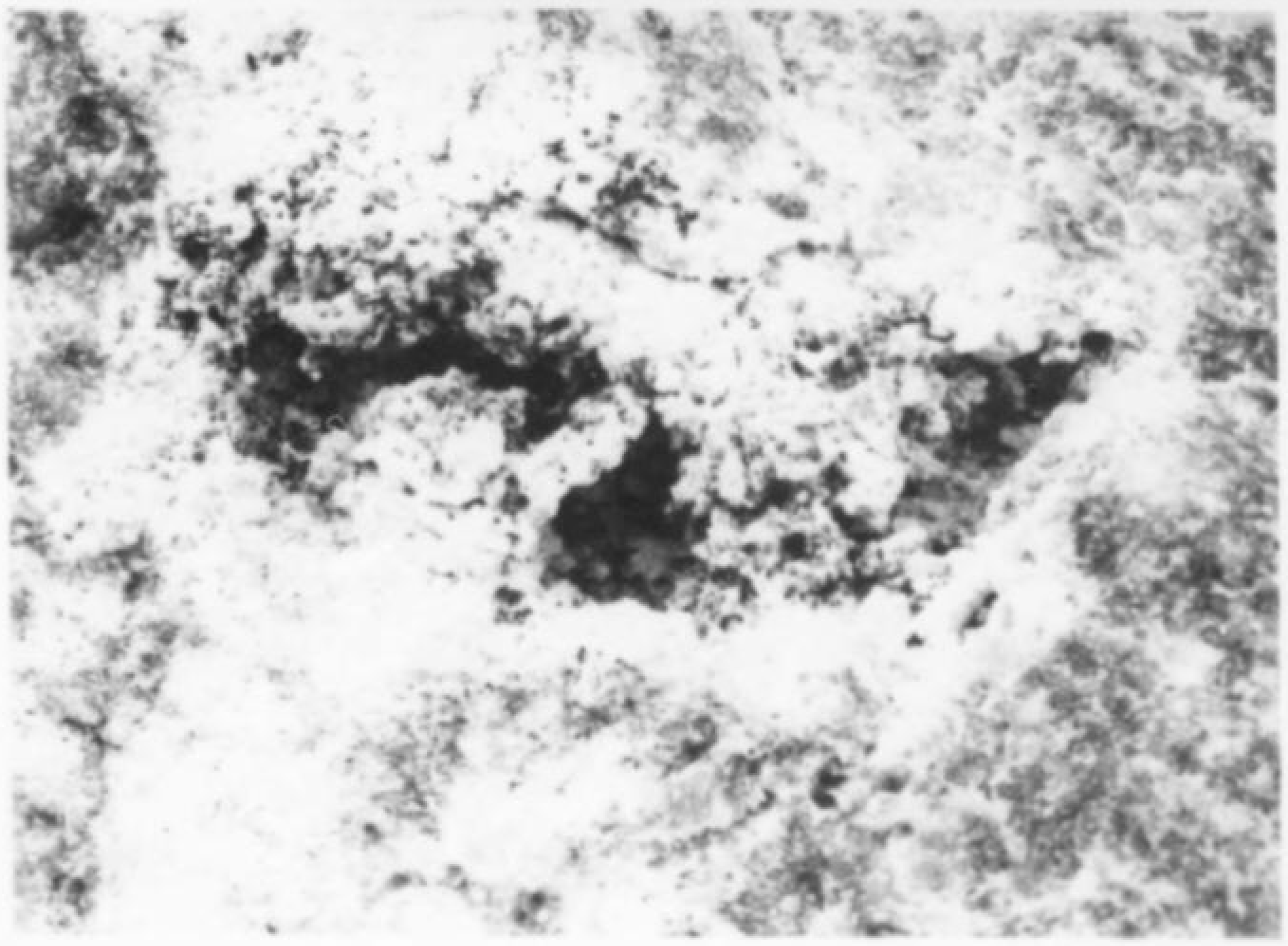


Figure 13. (top) **Common forms and habits of woodhouseite. The forms are $s\{01\bar{1}2\}$, $c\{0001\}$ and $d\{02\bar{2}1\}$.**

Figure 14. (top right) **Augelite crystal, 2.5 cm in length, showing *c, m, n* and *o* faces (see Fig. 15).**

Figure 15. (below) **Common forms of augelite, and the origin of the common stepped feature of the *c* face. The forms are $c\{001\}$, $a\{100\}$, $m\{110\}$, $n\{111\}$, $f\{201\}$, $x\{\bar{2}01\}$ and $o\{\bar{1}11\}$. Steps result from alternating *c* and *n* (as well as *c* and *o*) faces. See Lemmon (1935) for a complete listing of forms.**



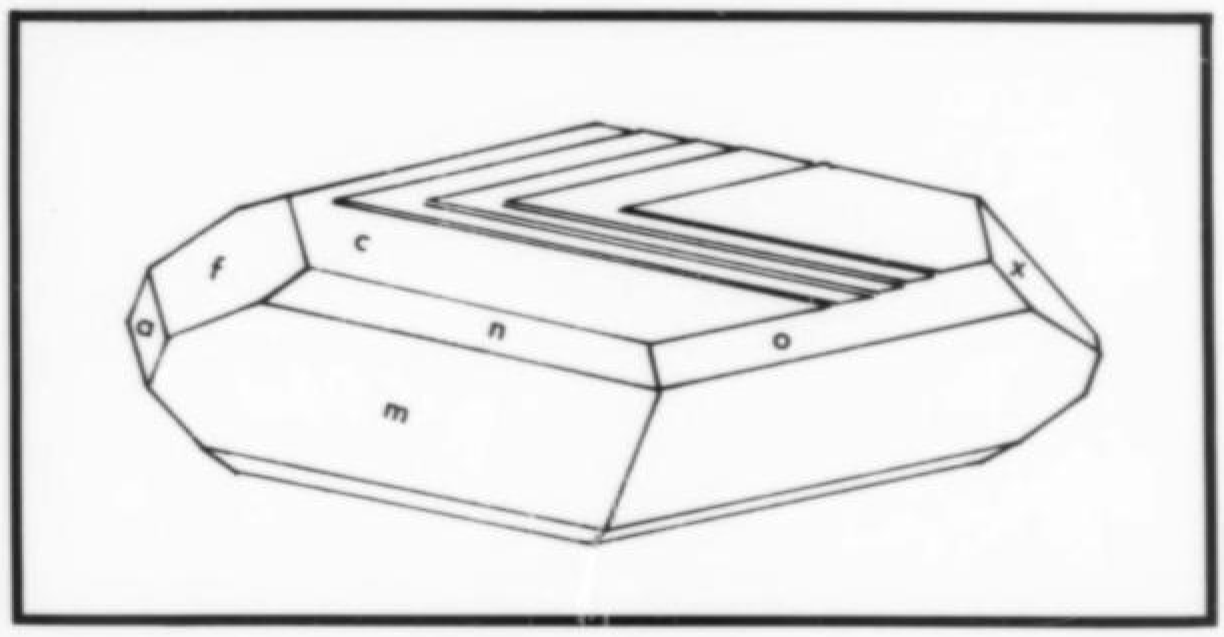
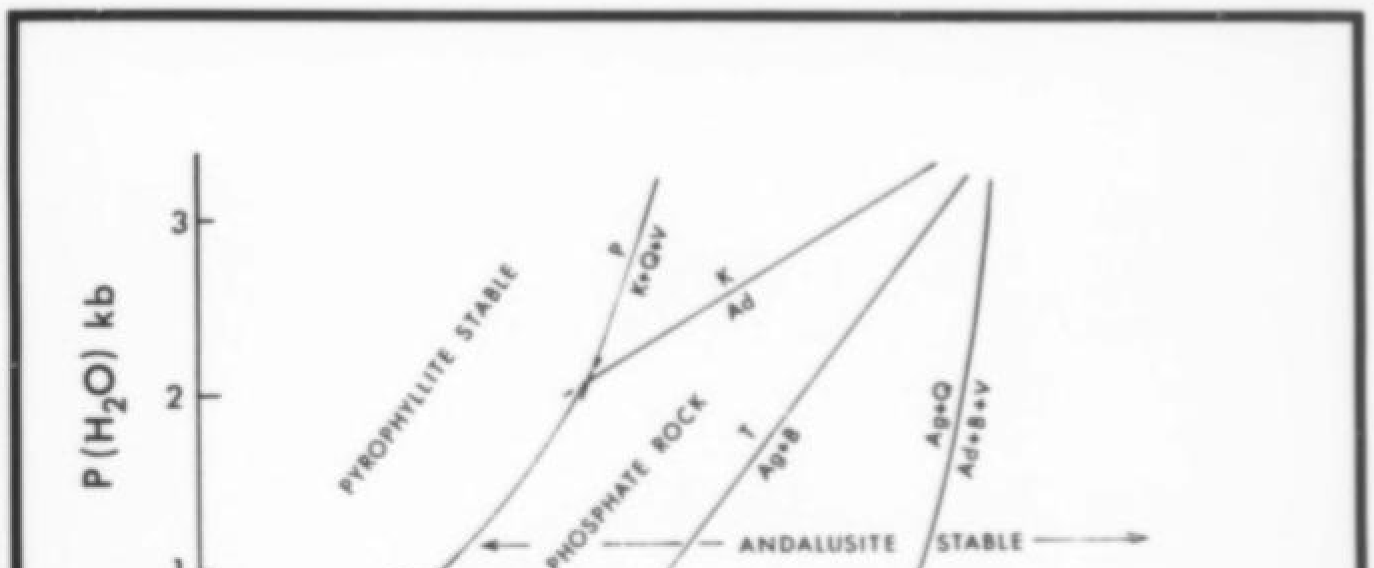


Figure 16. (center right) **Phosphate rock. Lightest areas are mostly augelite and topaz; darker, trolleite; nearly black, lazulite. Dark specks are rutile. Within the vug apatite and viséite have formed as a low temperature reaction. Width of the vug is 4 cm.**

Figure 17. (bottom right) **Pressure-temperature diagram illustrating the stability limits of some of the minerals occurring in the Champion mine. Andalusite probably formed at temperatures above 400°C, and the phosphate rock (augelite + trolleite) between about 350° and 450°C. Pyrophyllite can form only below about 325°C. Abbreviations: P = pyrophyllite. Ad = andalusite, K = kyanite, Q = quartz, V = water vapor, T = trolleite, Ag = augelite, and B = berlinite. Adopted from Wise and Loh (1976).**



and phosphoric acids from the nearby magma. Gross and Parwell (1968), who were primarily concerned with the rutile, felt the titanium was also introduced by high temperature fluids.

Wise (1975a) presented data and calculations to show that a muscovite-albite-quartz schist could be converted to an andalusite-quartz rock by reactions like:

$$2H^+ + 2KAl_2AlSi_3O_{10}(OH)_2 \rightarrow 3Al_2SiO_5 + 3SiO_2 + 2H_2O + 2K^+$$

acid + **muscovite** → **andalusite** + **quartz**

The H^+ participates in such reactions as an acidic fluid, even as a gaseous phase. The K^+ and Na^+ are carried away by the fluid. The results of such reactions (called hydrogen metasomatism) are commonly observed in porphyry copper deposits.

The advantages of this theory are that it accounts for the andalusite in the environment of volcanic rocks without appealing for special aluminous material or sediments. It also accounts for the widespread rutile. Crowder and Sheridan (1968, Table 2) show that the metarhyolite contains 0.5% TiO_2, probably as titanite. A reaction of an acidic fluid with titanite ($CaTiSiO_5$) might easily result in the formation of rutile and iron oxides.

If the acid in the fluid is largely hydrochloric, the main product will be andalusite or pyrophyllite. Local concentration of aluminum causes the formation of corundum or diaspore, depending on the temperature. A hydrofluoric acid component to the fluid will produce topaz, while boric acid leads to schorl and, as discussed above, phosphoric acid is necessary for the formation of trolleite and augelite.

These fluids could have originated in the nearby Cretaceous granitic intrusion. The fault zone provided a ready made channel for these fluids, concentrating their effects in one local area.

ACKNOWLEDGMENTS

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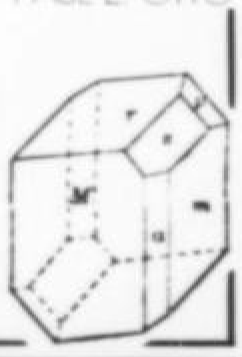
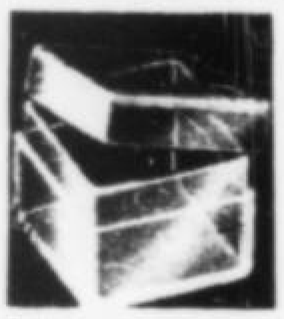




THE NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY;

OUT OF THE PAST AND INTO THE FUTURE

by Peter C. Keller and Anthony R. Kampf
Natural History Museum of Los Angeles County
900 Exposition Boulevard, Los Angeles, California 90007

MOST MINERALOGISTS, be they amateur or professional, would agree that California possesses more than its share of mineral wealth. Not surprisingly, the state also boasts perhaps the greatest concentration of mineral collectors in the U.S. Therefore it is only logical that California should have a public mineral and gem display of the highest quality. Such is the goal of the Natural History Museum of Los Angeles County. Presented here is a brief introduction to the museum, its rapidly growing mineral collection and, most importantly, its exciting new *Hall of Minerals and Gems.*

Figure 1. **The new North Entrance to the Los Angeles County Natural History Museum. The new Mineral and Gem Hall is located to the right of this entrance.**

The Natural History Museum of Los Angeles County is located in Exposition Park, across the street from the campus of the University of Southern California. Since it first opened its doors to the public in 1913, the Natural History Museum has grown steadily and today ranks as the finest museum of its kind west of the Mississippi. Within its walls a delicate balance of research

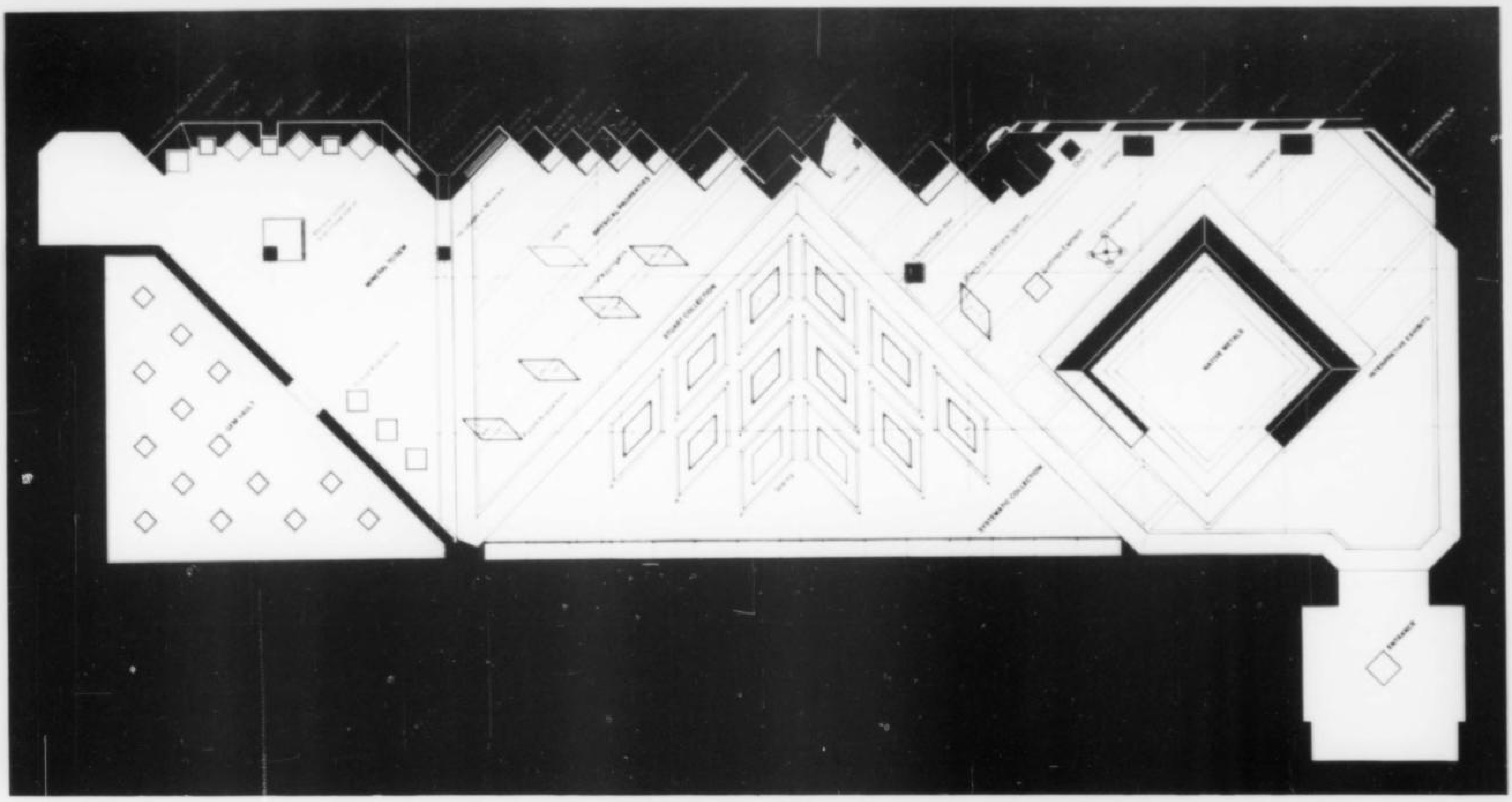


***Figure 2.* The floor plan of the new Mineral and Gem Hall. Its actual dimensions are about 134 x 42 feet.**

and exhibits is maintained to serve the public. Last year over 3 million people, more than 400,000 of them school children, visited the museum.

HISTORICAL BACKGROUND OF THE MINERAL COLLECTION

Geology has played an important role in the museum since the building was opened in 1913 primarily to house the huge collection of Pleistocene vertebrate fossils being excavated at the Rancho La Brea tar pits 10 miles away. The original building, however, consisted of art, science, and history exhibits, each housed in a 94 x 110-foot wing. The three wings met in a central rotunda which in recent years has housed the mineralogy exhibits.

Early museum records are vague, but it appears that the mineral collection had a slow and not very impressive start. Initially, minerals, shells, fish, amphibians, and reptiles were all included under the care of a single curator, zoologist Howard Hill. For brief periods in the 1920's, however, the mineral collection did benefit from part-time curators Arthur Tieje and R. T. Hill. (R. T. Hill is best known for his geological investigations in Texas and Mexico.) During this early period in the museum's history, mineralogy's role was expanded slowly by the acquisition of a number of small collections. In 1921 the mineral collection of the now defunct Chamber of Mines and Oils, an affiliate of the Los Angeles Chamber of Commerce, was acquired. This collection consisted principally of California and Arizona specimens and included a number of very fine specimens of Bisbee azurite and malachite. In 1923 the museum acquired a collection from the State Board of Mines. Other significant early acquisitions include the Crofts collection in 1927, the Johnson and Lukens collections in 1928, and the Last and Berray collections in 1932.

Mineralogy was finally established as a separate section in 1946 and Rene Engle was appointed part-time curator. Raymond Barber took over in 1950 and in 1952 oversaw the installation of the museum's first Mineral Hall, located in the rotunda of the original building. From 1955 to 1961 Thomas Clements, then head of the Geology Department at the University of Southern California, also served as part-time curator of mineralogy and petrology at the museum. During the 1950's William E. Phillips initiated the museum's gem collection with a series of annual gifts extending from 1953 to 1961. Notable among the Phillips gems are a 122-carat St. John's Island peridot, a 26-carat golden brown diamond, a 158-carat sinhalite (this stone is believed to be the world's largest), and a suite of 12 colored diamonds. In 1955 and 1956 the Fain and Blanch King collection was donated. The King collection is particularly strong in Illinois fluorite.

During the 1960's the collection continued to expand under the guidance first of Randall Chew III and then, in turn, of Robert Gaal, Jerry Matthews, and Bernard Fuller. This decade saw the donation of the Leon A. Salinger collection of fine opals; the Jay S. Smith collection of Franklin, New Jersey material; and the Mildred J. Groesbeck collection, which includes a particularly fine specimen of California gold (Fig. 4).

During the period 1971 to 1977 F. C. Hixon catapulted the museum's gem collection into national prominence through a series of very generous gifts from his personal collections. This period also marked a major change in the stature of the mineral collection. It was at this time that the commitment to construct a major mineral and gem gallery in the proposed new north wing of the museum was made largely through the intensive personal interest shown by the museum's Director, Giles W. Mead, and several members of the museum's Board of Governors. Mrs. E. Hadley Stuart, Jr., Douglas J. Macdonald, and Ed N. Harrison, in particular, have been instrumental to the success of this development program. In late 1976 mineralogy was brought under the new direction of the authors, Peter C. Keller and Anthony R. Kampf, associate and assistant curators, respectively. A large number of display-quality specimens were purchased immediately preceding and during this period of intense development. The most important source was the late Martin L. Ehrmann, who himself showed more than a monetary

Figure 3. **Exceptionally bright leaf gold, approximately 10 cm high, from the collection of the Los Angeles County Museum of Natural History. This specimen is from an unknown locality in the northern Sierra Nevada Province of California. (Photo by Harold and Erica Van Pelt, photographers, Los Angeles.)**

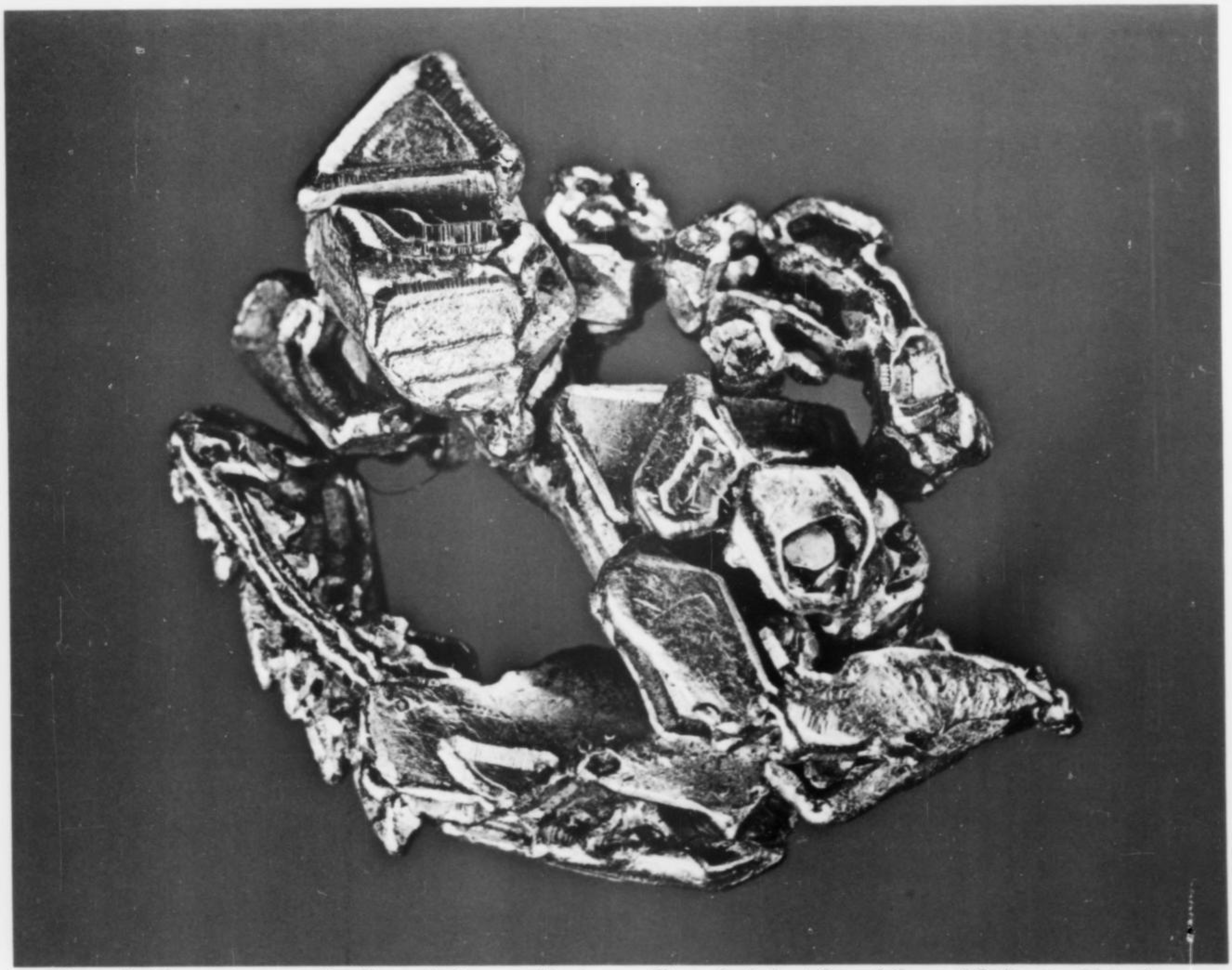
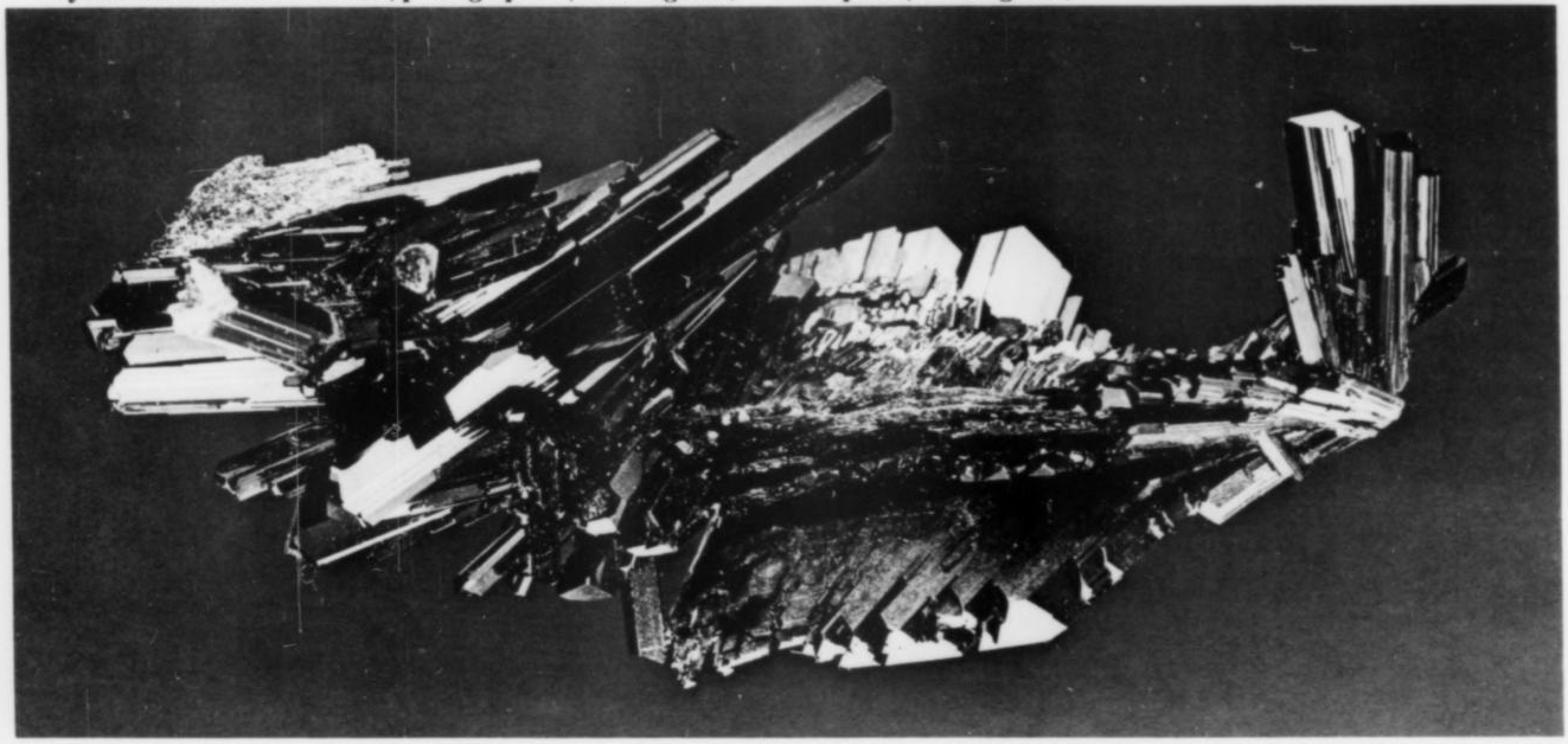


Figure 4. (above) **An exceptionally aesthetic crystallized gold from an unspecified locality in the Mother Lode Country of California. This specimen, from the museum's Mildred J. Groesbeck collection, is 2.5 cm across. (Photo by Harold and Erica Van Pelt, photographers, Los Angeles.)**

Figure 5. (below) **One of the world's finest epidotes from Untersulzbachtal, Austria. This specimen, on long term loan from Ed N. Harrison, is about 12 cm in maximum dimension. (Photo by Harold and Erica Van Pelt, photographers, Los Angeles.)**



interest in improving the museum's mineral and gem collection. Through Ehrmann, the museum purchased many of its finest specimens, which now form the nucleus of its display collection. During the development period several private mineral and gem collections were also purchased, notably the Sol Shalveitz collection of rough and cut tourmaline and the G. A. Alexander collection, which includes a 50-carat faceted alexandrite.

A PREVIEW OF THE NEW HALL OF MINERALS AND GEMS

In 1971 the Natural History Museum embarked on a $3.5 million campaign seeking private financial support for the vitally needed north wing expansion of the museum's exhibition, research, and educational facilities. An integral part of the new north wing facility is the new *Hall of Minerals and Gems*, which is scheduled to open early in 1978.

Innovative in concept and plan of execution, the new Hall of Minerals and Gems was designed by architect Joseph Wetzel of Stamford, Connecticut, to stress the basics of mineralogy in a spectacular atmosphere of simple elegance. Within the more than 5,600-square-foot area of the hall, (Fig. 2) 16 different exhibits will be employed to depict the basic principles of mineralogy in a unique, educationally oriented presentation that will stimulate both the interest and the senses of the museum visitor and will encourage a better understanding of the multifaceted nature of gems and minerals.

Prominently displayed in the main entrance to the Hall (located in the northwest corner of the museum's main foyer) will be a spotlighted pedestal case containing a group of spectacular mineral specimens welcoming the visitor to the exciting world of minerals and gems. In the distance, inside the doors to the hall, the visitor will be invited to explore further into the subject by a 3-½ minute orientation film that will be screening continuously and will present highlights of the fascinating story of the origin of minerals. Highly sophisticated film techniques including computerized animation, split-screen projection, and time-lapse photomicrography will be used. As the film ends, the film narrator directs the audience's attention to a huge, vividly colored artist's conception of a hypothetical cross-section of the earth's crust. Informative material, together with a display of actual mineral specimens set into the cross-section, will focus on the igneous, sedimentary, and metamorphic environments in which minerals form. After the mineral environments are explained, the visitor is free to move on and look out into the main body of the hall.

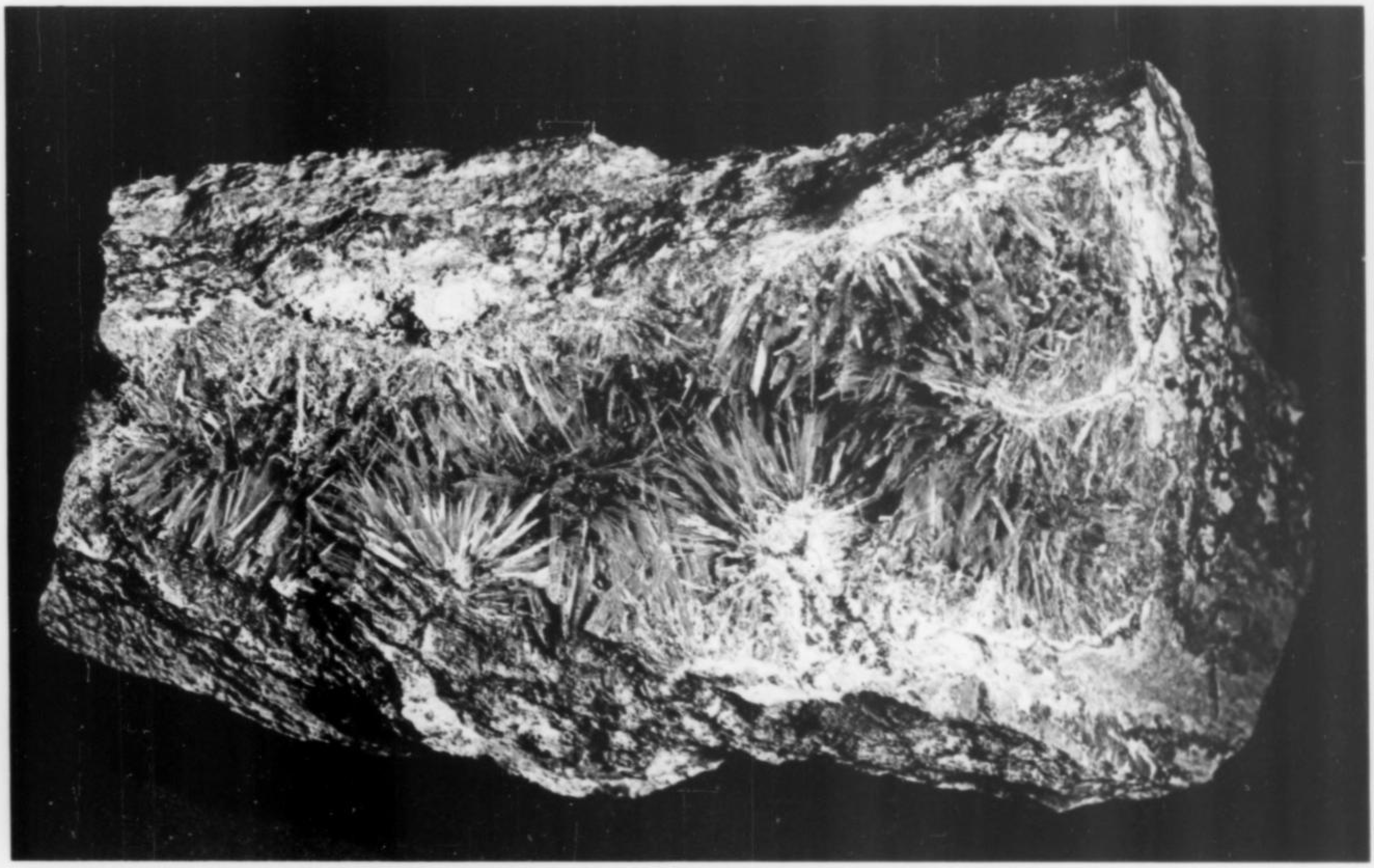


***Figure 6.* Cuprosklodowskite from Musonoi, Katanga. This specimen is approximately 10 cm long with needles up to 2 cm in length. (Photo by Harold and Erica Van Pelt, photographers, Los Angeles.)**

The hall's atmosphere is one of sheer elegance and beauty, perhaps more so than any other such hall in the world. In the center of the hall, under a dropped ceiling, will be a triangular arrangement of 12 specially designed parallelogram-shaped cases with granite bases and seamless Plexiglass tops. Housed in these unique cases will be outstanding mineral specimens—those that we think rank among the finest in the world and that should be especially enjoyed for their aesthetics and beauty. Some examples are such classics as a Kongsberg silver (Fig. 9), an Austrian epidote (Fig. 5), and a Zambian pyromorphite (Fig. 10). The outer six parallelogram cases will have spectacular specimens from the E. Hadley Stuart, Jr. collection. The Brazilian tourmaline cluster seen in Figure 7 is a fine example of the material from this outstanding collection.

If the visitor can resist examining the parallelogram cases for

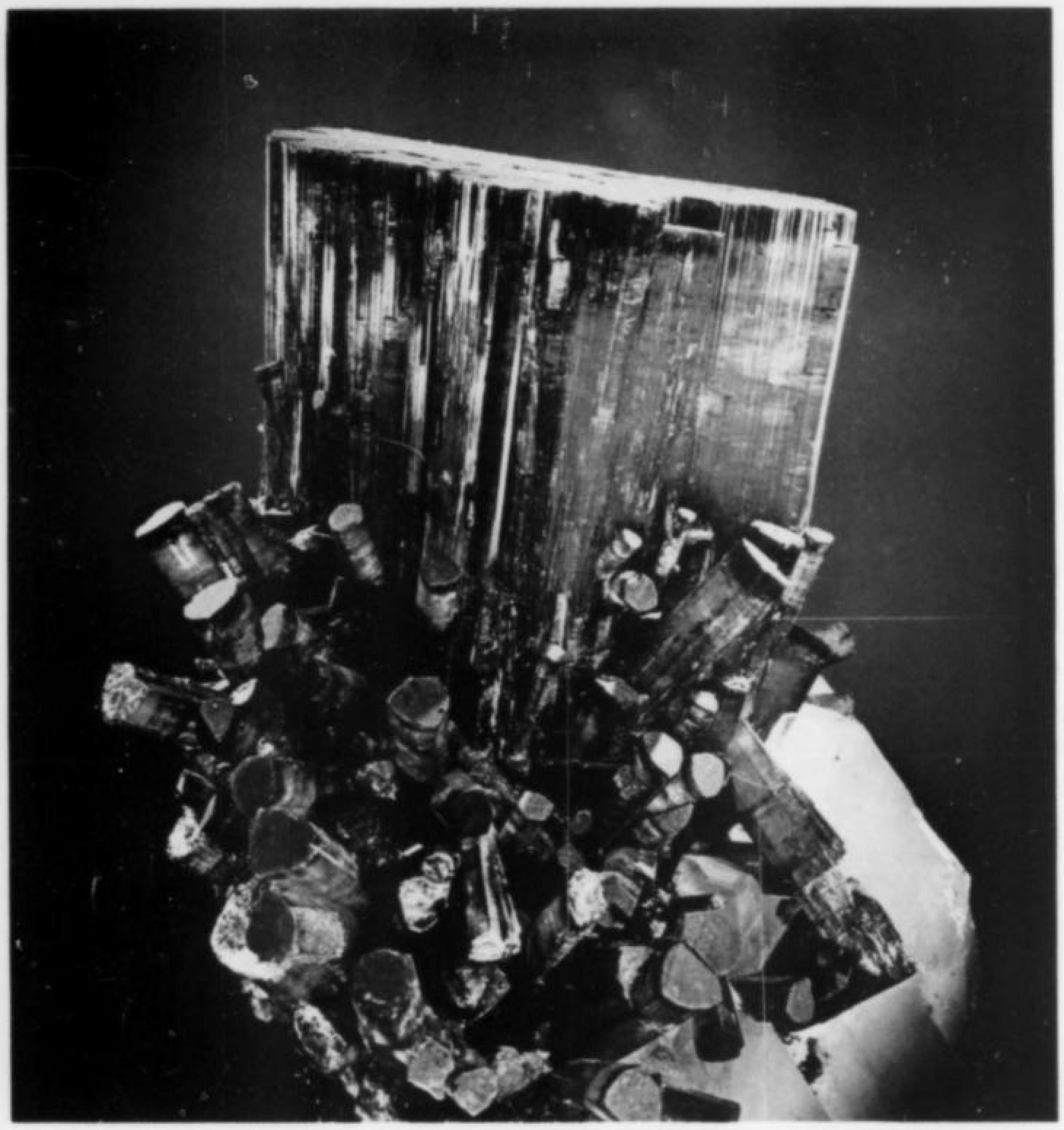


Figure 7. **Magnificant green tourmaline cluster on quartz from the Cruzeiro mine, Minas Gerais, Brazil (E. Hadley Stuart, Jr. collection). This specimen is approximately 40 cm high. (Photo by Harold and Erica Van Pelt, photographers, Los Angeles.)**

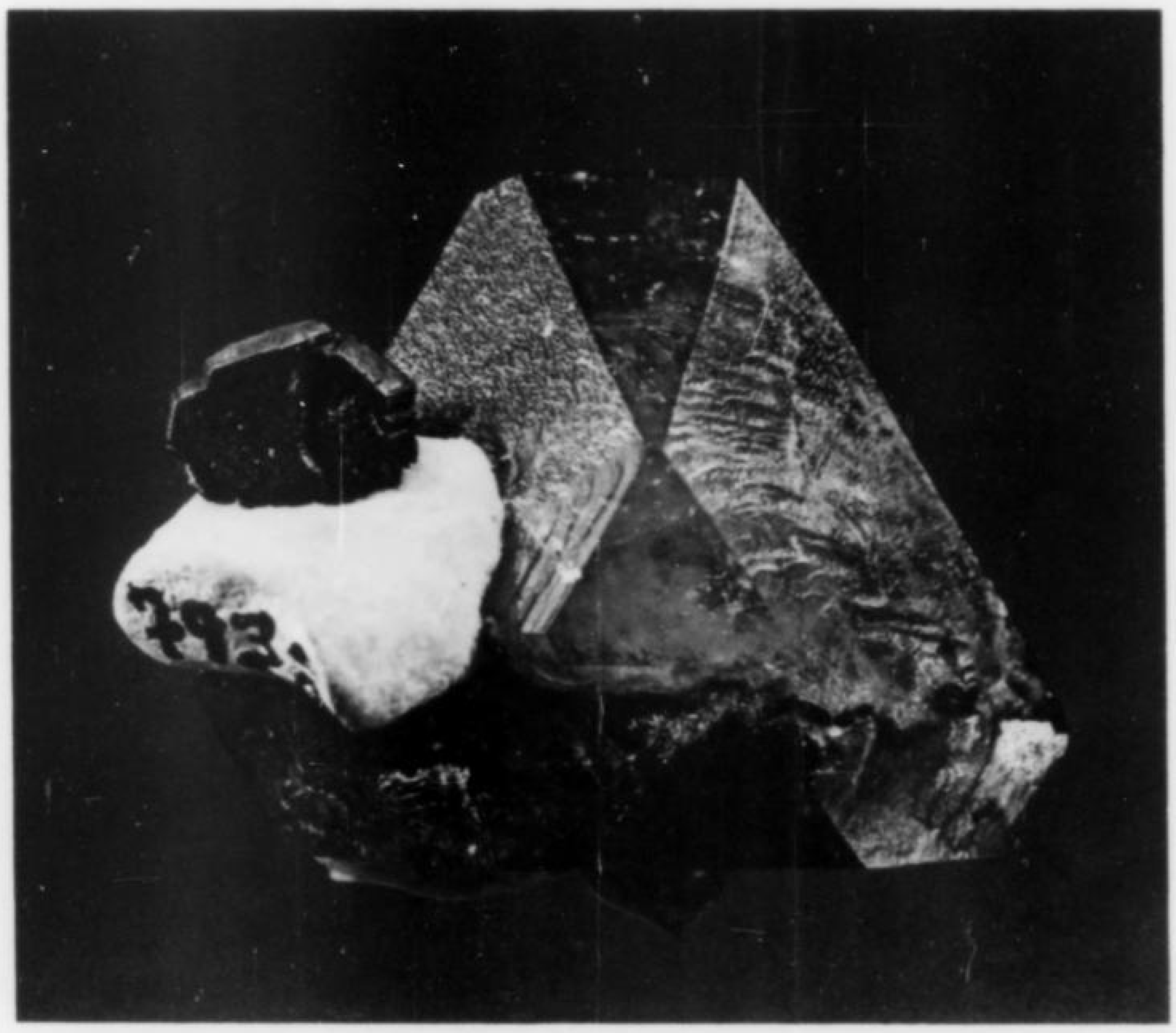
a while, he may continue along the north wall of the hall for a simplified yet thought-provoking lesson in the basic elements of mineralogy. This lesson includes peeking into the infinite atomic lattice of a quartz crystal while learning the complexities of defining a mineral. In the next exhibit, fiber optics will be employed to demonstrate how a mineral grows and how it can, under proper environmental conditions, change from an octahedron to a cube-octahedron and finally to a cube. An internally illuminated amethyst-lined lava tube over 3 feet deep will be set within a floor-to-ceiling graphical representation of a hydrothermal vein in an exhibit exploring how minerals need open spaces or "room to grow." Another north wall exhibit will teach the basic concepts of crystallography and the visitor will watch, with the aid of neon sculpture, how a simple, highly symmetrical isometric form degrades in symmetry step by step into a triclinic form. Fine examples of pseudomorphs will compliment the explanation of pseudomorphism. The fundamentals of mineral identification, based on their physical properties of hardness, streak, specific gravity, color, luster, and cleavage, will be illustrated in a series of highly descriptive exhibits. The educational exhibits along the north wall are concluded by three alcoves specially designed to prevent incoming white light. These will serve as an exhibit area for light-sensitive and fluorescent minerals.

Some minerals, if they satisfy certain important criteria such as durability, transparency, and brilliance, can be included in the world of gemstones. The interesting transition from an uncut mineral specimen to a gemstone will be explained in an area of the hall entitled *Minerals to Gems in the Americas*. The exhibit's concept is simple: we want to provide an introduction to the glittering world of the gem vault by telling the rarely explained history of gem-quality minerals prior to their appointment with the gemcutter. Six of the better-known American gemstones—tourmaline, beryl, sapphire, opal, turquoise, and spodumene—will be highlighted and their localities researched. The results of this research, on-location photography and collecting, will be incorporated into the presentation. An audio-visual presentation in a mini-theater will augment the exhibit and explain how the gems occur, how they are mined, how they are subsequently processed and, finally, how they are used by man.

With the *Minerals to Gems in the Americas* presentation as an introduction, the visitor will proceed into a magnificant gem vault. The triangular, vault can be described in one word: elegant. The walls are black granite, the floors are covered with deep burgundy carpeting. The vault is dark except for the spotlights in each of the 13 granite-based gem cases. With the recent donation of the F. C. Hixon collection, we believe that these unique cases will house one of the finest gem collections in the United States. To highlight the intrinsic value of the gems, they will be artistically displayed with the simplicity and beauty of a Tiffany display window. All this will be secured each evening by an impressive stainless steel vault door.

The "workhorse" of the Hall will be a 60-foot-long case along the south wall, containing the systematics collection, arranged according to Dana. In this exhibit, fine examples of the native elements, sulfides and sulfosalts, oxides, halides, carbonates, oxysalts, and silicates will be displayed. Each of the groups will be explained briefly and simply. Over 500 representative specimens

Figure 8. **A large, sharp benitoite crystal associated with natrolite and djurleite from the Benitoite Gem mine, San Benito County, California. This specimen is approximately 2.5 cm in diameter. Photo by Harold and Erica Van Pelt, photographers, Los Angeles.**



will be included in this portion of the hall.

Finally, since a significant part of California's history and early economic growth can be traced to the discovery and mining of gold, a large cove-like area in the east-central portion of the hall will be devoted to gold and its early recovery. Included in the display will be numerous examples of early mining tools and other artifacts of the Gold Rush, such as maps, daguerreotype photographs, and items made from California gold. The highlight of the exhibit, however, will be an exceptional collection of native gold in all its various forms (as in Fig. 3).

In addition to the new exhibit space, the mineralogy section will also have a new research and storage mezzanine located above the Mineral and Gem Hall. This area will house the museum's ever-growing reference collection of both minerals and gems. The collection and facilities will hopefully form an active area where interested mineralogists can come and study. In addition, the Gemological Institute of America will use the facilities (which include classroom space) for some of their classes.

The opening of the new Hall of Minerals and Gems early in 1978 will mark the culmination of untold man-years of effort, but at the same time it will mark the beginning of yet another phase in the growth of the Mineralogy and Geology Section of the Natural History Museum of Los Angeles County. An upcoming project of mammoth proportion will be the development of a comprehensive reference and display collection of California minerals. This will be an ongoing project that will depend heavily on fieldwork and the aid of local collectors. We hope that the California project, along with our continued personal interest in pegmatites and Mexican mineral localities, will lead to the development of a serious program of scientific research at the museum. At the same time, we will continue our efforts to acquire exceptional display specimens, so that we might constantly improve and expand the exhibits in the new Hall of Minerals and Gems. ⊠

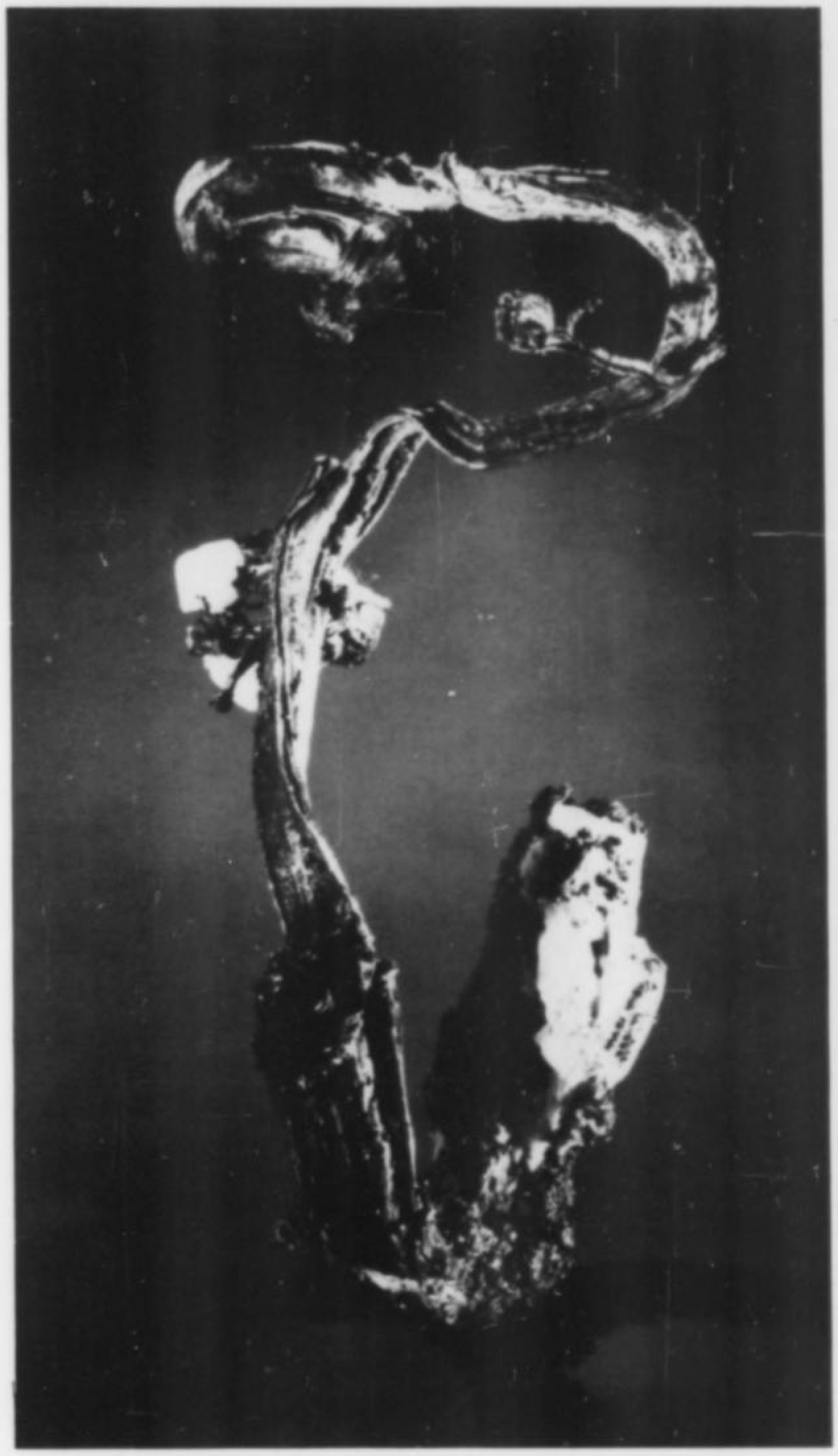


Figure 9. **A beautifully sculptured wire silver with calcite and acanthite from Köngsberg, Norway. The specimen is about 15 cm high. (Photo by Harold and Erica Van Pelt, photographers, Los Angeles.)**

Figure 10. **Pyromorphite crystals measuring up to 3 cm in length from Broken Hill, Zambia. (Photo by Harold and Erica Van Pelt, photographers, Los Angeles.)**

Figure 1. **Dioptase druse on matrix, 3.8 x 10 x 15 cm, from the Blue Bell mine.**

Figure 2. **Linarite with anglesite on matrix, 5 x 8 cm, from the Blue Bell mine.**

MINERALS OF THE
BLUE BELL MINE
SAN BERNARDINO COUNTY, CALIFORNIA

by Jack A. Crowley, 5881 Bellflower Drive, Newark, California 94560

INTRODUCTION

The Blue Bell mine, also known as the Hard Luck claims, is located in the Soda Mountains about 11 km west of Baker, California (see location map). It has produced a number of very attractive specimens of an assemblage of common to uncommon minerals, many of which have been found in unusual habits and extremely colorful combinations. The mine was described by Wright *et al.* (1953), although the location and some of the geologic descriptions are inaccurate. The mine is located in the SE ¼, Sec. 2, T 13 N, R 7 E, San Bernardino Meridian, and is shown as an unnamed adit symbol on the Soda Lake 15′ Topographic Quadrangle.

The mine was located in 1949 and produced ore in 1949 and 1950 as the Blue Bell and in 1951 as the Hard Luck claims. The complex ore yielded smelter returns of lead, zinc, copper, silver and gold (Wright *et al.*, 1953). The mine consists of several short adits and small stopes (Fig. 3). A single stope, open at the front, approximately 8 m deep, 8 m wide, and 5 m high (Fig. 4) has produced the mineral assemblage described here.

GEOLOGY

The geology of the Blue Bell mine area is complex, and has been outlined by Grose (1959). The rocks are a mixture of Mississippian-Pennsylvanian(?) metacherts, quartzites, and light colored, very fine grained, banded hornfels. Thin limestone beds that were present have been metasomatically replaced by assemblages of garnet and light colored calc-silicate minerals for hundreds of metres from their contact with Mesozoic granite. The granite contact is a short distance west of the workings. This granite has also been extensively altered by later hydrothermal fluids. The metallic mineralization probably occurred during this period of alteration. The metamorphic rocks of the mine area have been extensively intruded by numerous felsite dikes. These dikes have a northwest trend and make up nearly half of the exposed rocks in the mine area.

Faulting in the area appears to have been rather severe. The rocks within the stope and adjacent workings have been extensively fractured and broken. The roof of the main stope has a distinctly brecciated appearance, with some blocks up to 1.5 m on a side. Working within the stope is rather hazardous due to the broken nature of the rock. A large number of fractures have been partly filled with secondary minerals during oxidation of the deposit. Throughout the area extensive alteration has disguised many of the original rocks and their relationships.

MINERALOGY

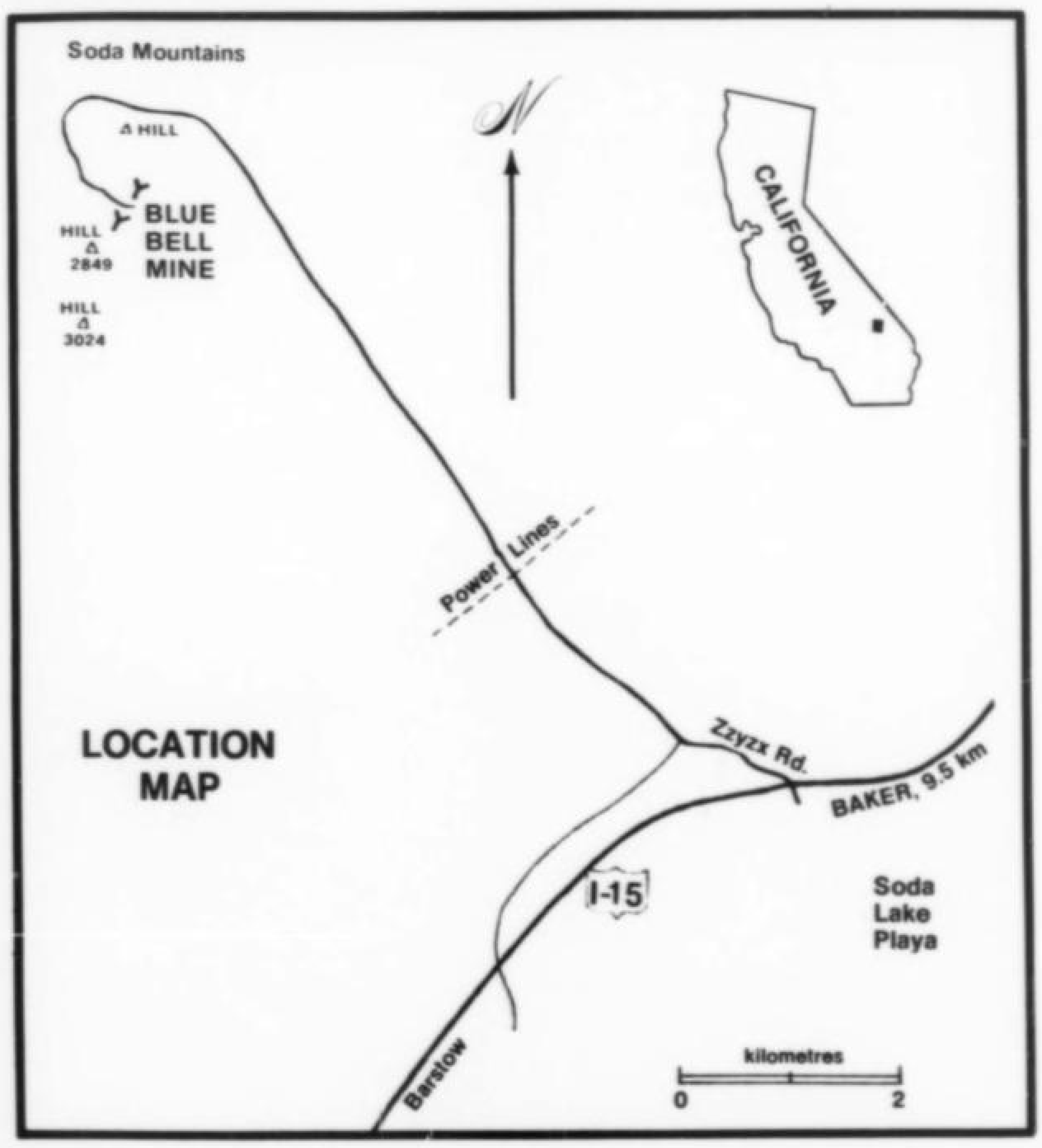
The hypogene minerals apparently consisted of **galena, sphalerite, chalcopyrite,** specular **hematite,** and **quartz**. Sphalerite and galena have not been seen, but the ubiquitous nature of the secondary lead and zinc minerals suggests they were originally present. The original silver bearing mineral is unknown. Pyrite appears to have been missing from the hypogene assemblage, and this may have been a significant factor in the secondary assemblage that formed.

Oxidation is nearly complete, and the ore mined in the past must have been almost exclusively composed of oxidation products of the original sulfides. The following supergene (oxidized zone) minerals have been identified by X-ray diffraction and optical means: **anglesite, brochantite, calcite, caledonite, cerussite, chlorargyrite, chrysocolla, dioptase, fluorite, hemimorphite, leadhillite, linarite, quartz, rosasite** and **wulfenite.** With the exception of rosasite, all the minerals listed above are relatively common in the oxidized ores. See Table 1 for the mineral paragenetic sequence.

The secondary minerals in the mine formed in numerous small fissures which criss-cross the ore body. Most of these fissures are a few mm or less in width. The minerals formed either as stubby crystals oriented normal to the fissure in which they grew, or as long bladed crystals parallel to the sides of the fissure. No large open cavities or vugs with secondary minerals crystallized in them have been found. The limonitic gossan so frequently accompanying weathered sulfide deposits is poorly developed at the Blue Bell mine. The limonitic minerals, although present, are relatively minor in amount. Generally the oxidized zone has a light tan to light greenish-yellow or light brownish-green coloration.

Anglesite $PbSO_4$

Anglesite is present as coatings of milky white subhedral crystals which have a greasy luster. It is commonly coated with linarite (Fig. 2) and more rarely with caledonite (Fig. 6) or brochantite, creating very attractive specimens. Anglesite also occurs as brilliant colorless crystals in druses with linarite and caledonite on them.



Brochantite $Cu_4(SO_4)(OH)_6$

Brochantite occurs as deep green crystals of acicular to stubby prismatic habit. It usually occurs with linarite and also commonly replaces linarite. Brochantite usually is not found with minerals other than linarite. Rare associations include anglesite, hemimorphite, and caledonite.

Calcite $CaCO_3$

Calcite was one of the last minerals to crystallize at the Blue Bell mine. It occurs as rhombohedrons usually associated with dioptase and as curved bladed crystals found throughout the mine.

Caledonite $Pb_5Cu_2(CO_3)(SO_4)_3(OH)_6$

Caledonite is one of the more colorful minerals in the mine. It occurs as fine, flat-lying bright turquoise-blue crystals up to 2 cm in length. It also occurs as stubby prismatic crystals up to several mm long growing from the sides of fissures. The terminations are generally somewhat round and poorly developed. Caledonite is found with linarite, leadhillite, anglesite, and rarely with cerussite and dioptase. Caledonite is one of the early minerals. Linarite usually crystallized before or at the same time as caledonite and they commonly grade into each other in the same crystal. Fine druses of caledonite measuring up to 10 x 15 cm have been found with linarite and/or leadhillite and undoubtedly larger and finer specimens were found during mining.

Cerussite $PbCO_3$

Cerussite is somewhat less common than the sulfates and does not form particularly attractive crystals. Cerussite occurs as milky white subhedral coatings of individual crystals which are up to 1 cm long, and as crystal druses with bladed habit. The bladed crystals usually are stained red-brown. They seldom attain a length of more than a few mm. There were two periods of cerussite formation. The bladed crystals pre-date the sulfates and have linarite, caledonite, and leadhillite formed on them. The milky crystals formed late in the sequence.

Chlorargyrite $AgCl$

Chlorargyrite is inconspicuous but relatively common when looked for. It is associated with chrysocolla, quartz, and dioptase in black to brown siliceous ore. The chlorargyrite occurs as brown to purplish brown cubes and cubo-octahedrons. The crystals are seldom over a few mm in size.

Dioptase $CuSiO_2(OH)_2$

Dioptase occurs in the peripheral area of the ore body. It crystallized late in the sequence and occurs as brilliant, light emerald green druses of micro-crystals found upon most of the minerals present (Fig. 1). The crystals are acicular to rod shaped and have both flat and pyramidal terminations. Dioptase is commonly associated with chrysocolla. Chlorargyrite frequently coats the dioptase crystals. The dioptase crystals make attractive micromounts, especially when found with leadhillite, wulfenite, or chlorargyrite. Plates of up to 20 cm on a side have been found with a solid layer of micro-dioptase on one or more faces.

Fluorite CaF_2

Fluorite occurs as colorless, transparent cubes and octahedrons. The cubic form is most common. Fluorite crystallized late and crystals have been found on all the minerals except brochantite. The largest fluorite crystal seen was a 5 mm cube.

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Hemimorphite is common in the peripheral areas of the ore body. It is generally found in the same area as dioptase and other silicates. The crystals are small, transparent blades.

Leadhillite $Pb_4(SO_4)(CO_3)_2(OH)_2$

Leadhillite is one of the earlier crystallized minerals of the secondary mineral group. It forms good pseudohexagonal crys-

Table 1.
Paragenetic Sequence of Secondary Minerals

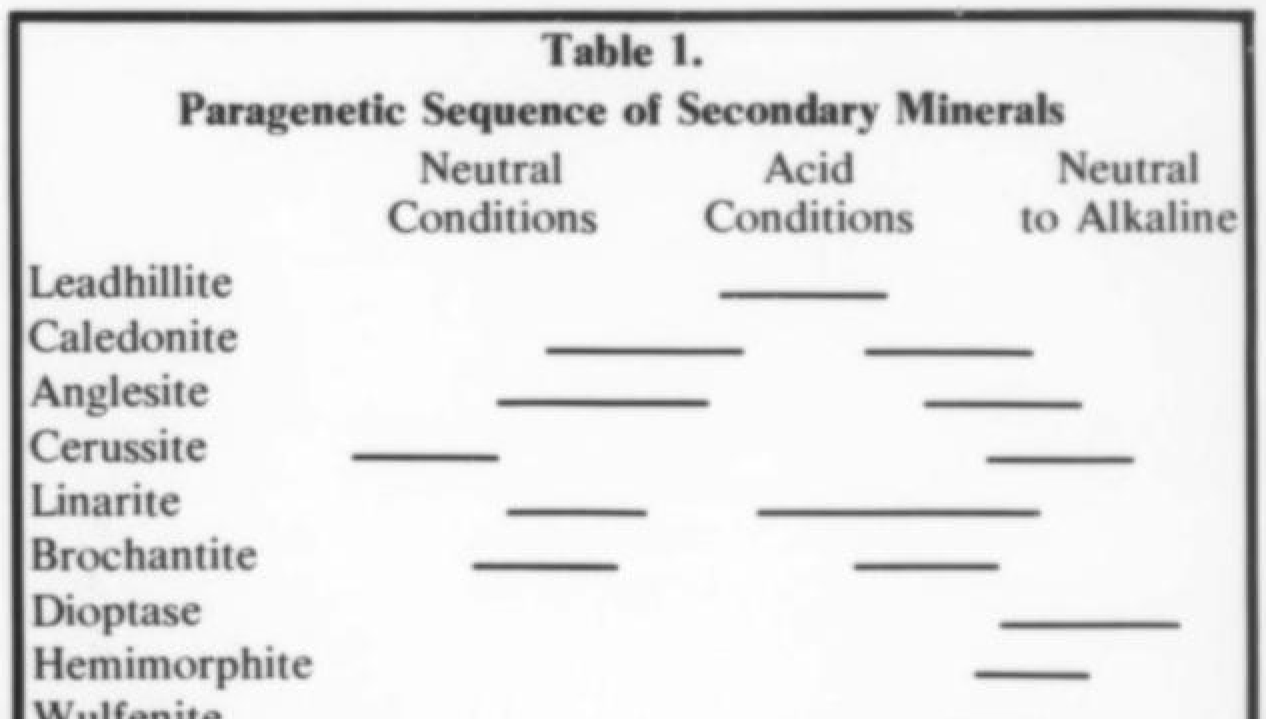


Figure 3. **The Blue Bell mine area (mine indicated by arrow). This view is toward the southeast.**

tals with the *c* axis approximately normal to the matrix and also with the *c* axis parallel or slightly inclined to the matrix. Individual crystals are seldom more than a few mm in size, and form aggregates measuring up to several square cm in area. Leadhillite is found as colorless to pale ice blue, milky coatings commonly associated with caledonite (Fig. 5) and less commonly with linarite. It rarely occurs with dioptase and cerussite. It has not been found associated with anglesite.

Linarite $PbCu(SO_4)(OH)_2$

Linarite is the most common secondary mineral present at the Blue Bell mine. It forms druses and crusts of brilliant royal blue crystals (Fig. 2). Bladed crystals up to 3 cm long are relatively common. The longer crystals rarely have good terminations due to contact with the matrix or other crystals. Smaller crystals are transparent and usually have good terminations. The crystals are striated parallel to the long axis. Linarite crystallized early and again during the middle of the paragenetic sequence. Linarite crystals with cerussite cores have been seen in some specimens. This suggests that linarite replaced cerussite. Linarite is often replaced by caledonite or brochantite. In some cases the reverse situation has occurred.

Quartz SiO_2

Quartz occurs as tiny transparent, sparkly crystals associated with the silicate minerals. It appears to have crystallized late in the sequence.

Rosasite $(Cu,Zn)_2(CO_3)(OH)_2$

Rosasite occurs as a light green, fuzzy, powdery coating occasionally found on some of the other minerals.

Wulfenite $PbMoO_4$

Wulfenite is present in two forms. Small, bright yellow to orange-yellow amoeba-like blebs lying flat on the matrix are most common. It also is found as crystals of varying forms about 1 mm in size. Wulfenite crystallized late in the sequence and usually occurs by itself or on dioptase.

PARAGENESIS

The great variety of minerals, reversals in crystallization sequence, and rapid changes in mineral assemblages in the same fissure both vertically and laterally over the space of a few cm or less make the application of Eh-pH diagrams difficult. The Eh-pH conditions in the solutions apparently changed considerably during secondary mineral formation. Some general observations can be made about the assemblages however. Conditions were initially near neutral, which allowed the cerussite to form. With time, the solutions became progressively more acidic and finally a reversal toward higher pH and eventually mildly alkaline conditions occurred. The acidic conditions through most of the time of secondary mineral formation would account for the general lack of limonitic minerals in the Blue Bell mine, the iron having been carried away by the acid solutions. In addition, a pyrite-deficient hypogene assemblage would also help to explain the lack of limonitic material.

According to Jarrell (1944) brochantite forms from mildly acid, dilute sulfate solutions. The transition from neutral to acidic conditions probably coincided with the formation of brochantite. Then the transition from acidic to alkaline conditions occurred after the formation of the second stage brochantite. The formation of the hemimorphite-dioptase-wulfenite mineral assemblage then occurred under neutral to alkaline conditions, after the cessation of the crystallization of brochantite. The solutions in the ore body were initially copper bearing, and became progressively enriched in lead and other ions as oxidation progressed and pH dropped. These types of conditions would explain the assemblage in order of crystallization of brochantite → linarite → caledonite+anglesite. When conditions began to change towards higher pH, these minerals again came into their stability field and crystallized in the reverse sequence; caledonite → linarite → brochantite with excess lead forming anglesite or combining with carbonate to form cerussite. As stated by Takahashi (1960), anglesite and cerussite are metastable under neutral conditions.

Figure 4. **Entrance to the Blue Bell mine stope containing the minerals discussed in the text.**

The tendency for the minerals present to form parallel to the sides of the fissures, rather than normal to the sides is interesting. This has been the tendency even in some of the wider openings. This can possibly be explained by the thoroughly broken nature of the rock with generally narrow fractures in a somewhat non-reactive siliceous matrix. Groundwater entering the system can rapidly disseminate into the fissures and work its way downward in a one-way system. In very narrow fissures this might be a slow process. When the fissure widens the water would tend to remain as a thin coating, moving downward along the sides of the fracture and never completely filling the opening. Reaction and crystallization would then take place within this layer of water and crystals would have a tendency to form parallel to the sides of these fractures. This would explain the common occurrence of normally free-standing crystals such as linarite, wulfenite and cerussite to form flat bladed crystals lying flat on the wall rock. With a badly brecciated, near-surface ore mass, evaporation may also be a factor in the crystallization

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VUAGNATITE

from California

by Adolf Pabst*, Richard C. Erd**, Fraser Goff**, and Leo Rosenhahn***

Figure 1. (top) **The site of Keith Rhea's original find of vuagnatite (view looking to the west from the Miner Ridge jeep trail).**

NEW occurrences of vuagnatite, **$CaAlSiO_4(OH)$**, are described from several localities in Mendocino County, California. The principal occurrence is at Red Mountain in rodingitized metagabbro dikes in serpentinized peridotite of Mesozoic age. Here vuagnatite is associated with hydrogrossular, idocrase, chlorite, and various copper minerals. Vuagnatite in diverse lithologies has been found in cobbles in the Russian River near Cloverdale. Vuagnatite occurs both as prismatic and as disphenoidal, colorless, euhedral, orthorhombic crystals.

Vuagnatite has H = 6, Sp. Gr. = 3.42(2), and a conchoidal fracture. It is brittle, colorless to pale brown (rare), and nonfluorescent. Vuagnatite is biaxial negative with α = 1.701(2), β = 1.724(2), γ = 1.727(2), and $2V_{\alpha}$ = 44(1)°; X = *c*, Y = *b*, Z = *a*; rarely pleochroic with X (colorless or yellowish brown) $>>$ Y,Z (colorless); $r < v$, strong. Space group $P2_12_12_1$ with $a = 7.0538(4)$Å, $b = 8.5410(4)$, $c = 5.6839(3)$; Z = 4[$CaAlSiO_4(OH)$]. Electron-microprobe analyses of five crystals show the following ranges (in wgt. percent): **Ca** 22.10-22.26, **Al** 14.96-15.24, and **Si** 16.04-16.20.

INTRODUCTION

The story of California vuagnatite properly begins with its discovery in 1965 and 1966 by Keith Rhea during work on "Geology of the Red Mountain area, Lake and Mendocino Counties, California," for his M.S. degree at the University of California, Berkeley. The first material found occurred as small veinlets in a sheared metagabbro composed mainly of hydrogrossular and chlorite together with minor amounts of native copper and chalcocite. Rhea described the occurrence and optical properties of the unknown mineral, and Pabst determined the space group $P2_12_12_1$, in the orthorhombic disphenoidal class, and the cell dimensions.

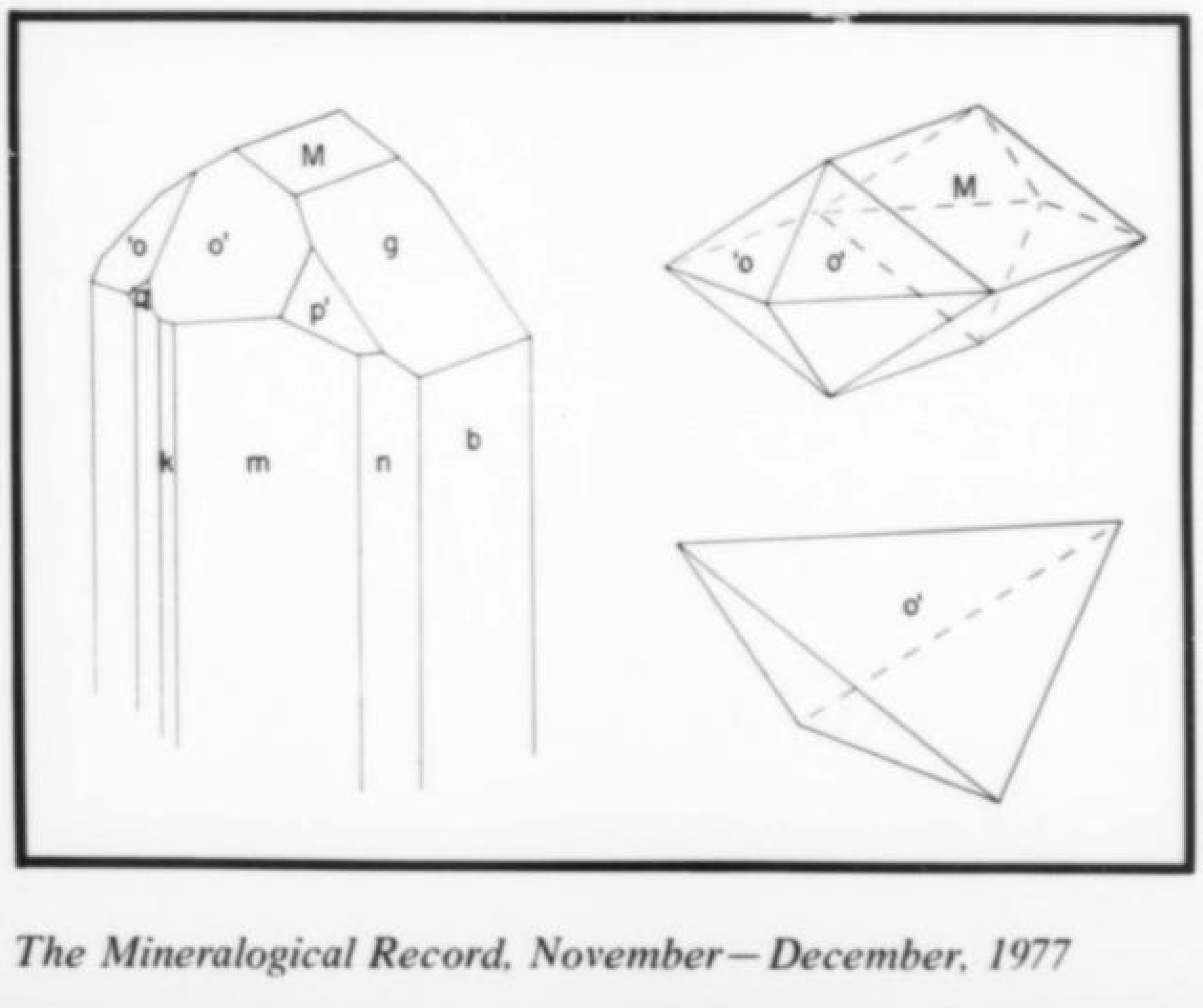

Figure 2. (left) **Drawings of various crystal habits of vuagnatite.**

No further work was done until, eight years after Rhea's discovery, one of us (LR) found vuagnatite in tiny disphenoidal crystals enclosed in calcite veinlets, together with prehnite, xonotlite, calcite, fibrous idocrase, and hydrogrossular. These minerals were found in a Russian River cobble, just north of Cloverdale, Mendocino County, California, near the locality where rosenhahnite was discovered (Pabst *et al.*, 1967). The rock is a microbreccia composed chiefly of light-green pumpellyite and pink diopside. Rosenhahn determined the optical properties of the Russian River material and brought the specimen to Erd for X-ray study. At this point, we realized that it matched Rhea's Red Mountain mineral. Rosenhahn returned to Rhea's locality (Fig. 1), where new exposures had since been made, and found beautiful, euhedral, prismatic crystals showing many forms (Fig. 2 through 6). So different are these crystals in appearance from those found at the Russian River that they are not easily recognized as the same mineral. Complementary disphenoids generally occur together on the Red Mountain vuagnatite, such that the crystals appear holohedral. The simple disphenoid {111} of the Russian River vuagnatite makes their true symmetry readily apparent (Fig. 2, lower right, and Fig. 3,

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upper left).

In March of 1975, when vuagnatite was submitted to the IMA Commission on New Minerals for approval on the basis of an occurrence in Turkey (Sarp *et al.*, 1976), we immediately recognized that this was Rhea's unknown. Some weeks later Akira Kato, Chairman of the IMA Commission, wrote that he and Matsubara had found vuagnatite in Japan. Shortly thereafter, Erd, Pabst, and Ed Oyler, guided by Rosenhahn, visited Rhea's locality and the same day Rosenhahn found yet another occurrence of vuagnatite 380 metres away. The mineral is now known in at least six localities, as Sarp *et al.* (1976) mention an occurrence in Guatemala yet to be described.

OCCURRENCE

There is a striking similarity in the worldwide occurrences of vuagnatite so far known, with the exception of the Russian River cobbles. All are in rodingitized gabbros, or in what Coleman (1967) terms "reaction zones." These are metasomatically altered rocks, characterized by loss of silica and alkalis and enrichment in lime and water, associated with serpentinized alpine ultramafic bodies. The ultramafic bodies are segments of the earth's mantle that moved up into the crust and were altered, at relatively low temperatures and high pressures, as this movement took place (Coleman, 1967; Honnorez and Kirst, 1975).

At Red Mountain, vuagnatite occurs both as a late vein and rock-forming mineral in rodingitized metagabbro dikes in a serpentinized peridotite of Mesozoic age. Rhea's original find of vuagnatite is from an outcrop of a reaction zone in the peridotite very near its contact with the enclosing Franciscan formation of Jurassic-Cretaceous age. The exact location is just west of Miner Ridge, 1.50 km N 40° W of Red Mountain peak (VABM 3389 on the Purdys Garden, California, 7½′ quadrangle), where vuagnatite occurs as veinlets and in vugs (Fig. 4) associated with hydrogrossular, fibrous to prismatic idocrase, chlorite (several species), native copper, copper sulfides (chalcocite, chalcopyrite, and minor covellite), and supergene copper minerals (cuprite, chrysocolla, malachite, and azurite). Diopside is prominent in the rodingite at this locality, but not in direct association with vuagnatite. The second locality, also within the ultramafic mass, is a prospect cut (Copper King No. 2), 1.12 km N 39° W of the Red Mountain peak, where vuagnatite occurs as crusts or veins in a rock that consists of ninety percent or more of ripidolite (a high-iron chlorite) and vuagnatite. Accompanying the crusts of vuagnatite is a greenish-blue mineral that will be described in a later paper. Some of the vuagnatite crystals at both localities are encrusted with goethite.

The vuagnatite first found in the Russian River cobbles (described above) is also part of a typical rodingite assemblage. However, a second cobble found at this place is a microbrecciated graywacke composed mostly of quartz, plagioclase, and sericite with minor calcite, barite, vuagnatite, and titanite. The occurrence in this last rock type is tantalizing in that it shows that vuagnatite is not limited to the rodingite association. So far all attempts to locate the source of these cobbles have been unsuccessful.

PHYSICAL PROPERTIES

Vuagnatite is colorless, has a vitreous luster, and is nonfluorescent. The mineral has a hardness of 6, is brittle, and has a conchoidal fracture. The specific gravity of vuagnatite, measured in Clerici solution with simultaneous determination by a Westphal balance, is 3.42(2). Compared with other calcaluminosilicates, vuagnatite has a relatively high density and a low volume per oxygen. This is in accord with its occurrence in rocks metamorphosed under conditions of low temperature and high pressure.

CRYSTAL MORPHOLOGY

Vuagnatite at the Red Mountain locality occurs as prismatic crystals up to 3 mm in length elongate on *c* or *a*. Crystals from this locality show many forms; of the eighteen forms found to date, only half can be conveniently shown on the drawings in

TABLE 1. Unit cell and optical data for vuagnatite.

	Red Mountain	*Russian River*	*Turkey*[a]
a (Å)	7.0538(4)	7.0539(4)	7.055(6)
b (Å)	8.5410(4)	8.5396(3)	8.542(7)
c (Å)	5.6839(3)	5.6833(2)	5.683(5)
V (Å^3)	342.44(2)	342.35(2)	342.48
Z	$4[CaAlSiO_4(OH)]$	$4[CaAlSiO_4(OH)]$	$4[CaAlSiO_4(OH)]$
D (calc.)	3.41_6	3.41_7	3.42
D (meas.)	3.42(2)	n.d.	3.20-3.25
Space group	$P2_12_12_1$	$P2_12_12_1$	$P2_12_12_1$
α	1.701(2)	1.702[b]	1.700(1)
β	1,724(2)	1.726	1.725(1)
γ	1.727(2)	1.728	1.730(1)
$2V_\alpha$	44(1)°	35 - 40°, est.	48°
Orientation	X = c Y = b Z = a	X = c Y = b Z = a	X = c Y = b Z = a
Pleochroism	X (colorless or yellowish-brown) >> Y, Z (colorless)	Colorless	Colorless
Dispersion	$r < v$, strong	$r < v$	$r < v$, very strong

a Data from Sarp *et al.* (1976).
b Determinations by Leo Rosenhahn.

Figure 3. **Crystals of vuagnatite exhibiting various habits. The crystal at the top is 0.4 mm in the longest dimension.**

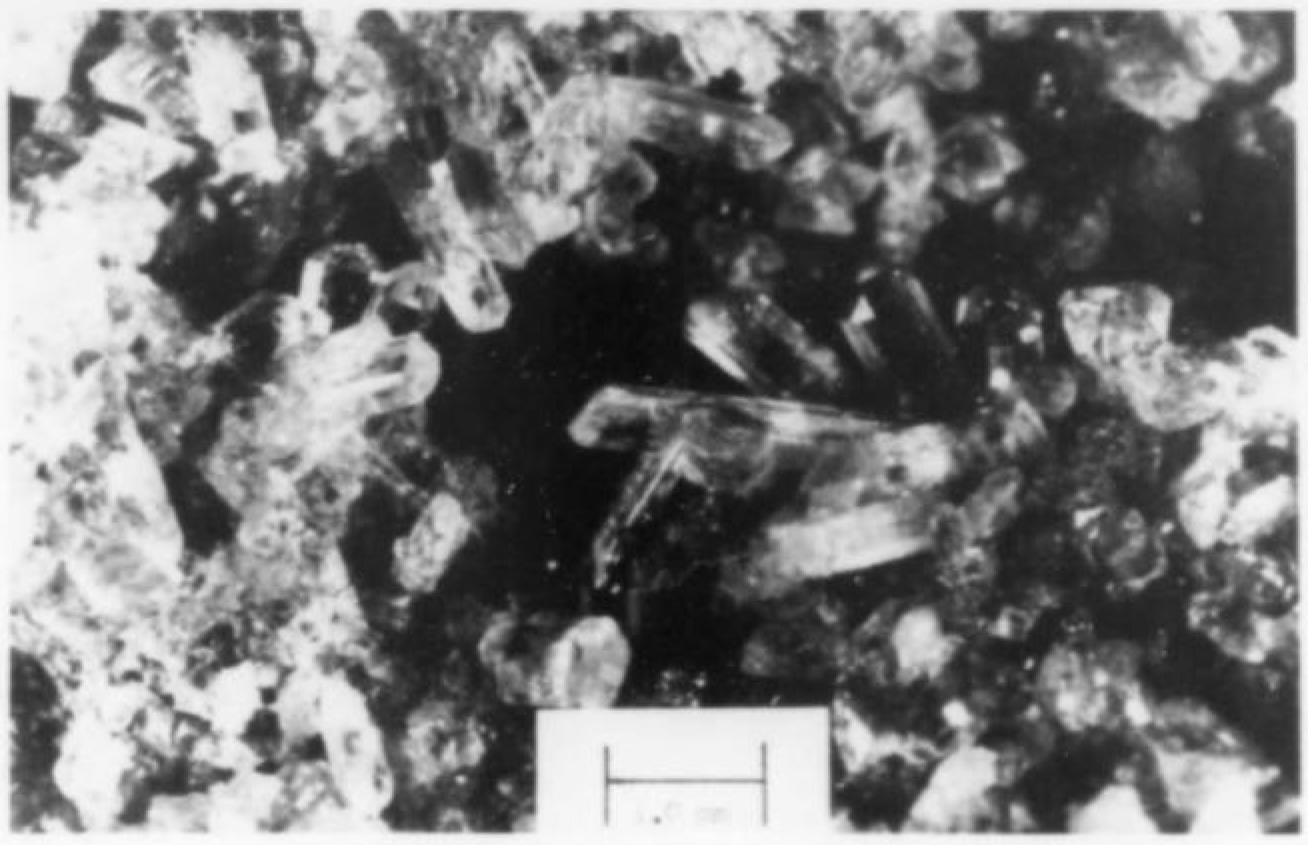

Figure 4. **A vug lined with vuagnatite crystals from the Red Mountain locality.**

TABLE 2. X-ray powder diffraction data for vuagnatite.

h k l	d(calc.)* (Å)	d(obs.)** (Å)	I	*h k l*	d(calc.)* (Å)	d(obs.)** (Å)	I
110	5.439	5.440	21	103	1.830	1,829	7
011	4.732	4.716	12	240	1,826	1.825	9
101	4.426	—	—	113	1.789	1.789	14
020	4.270	4.273	9	312	1.772	1.772	14
111	3.930	3.930	43	400	1.763	1.764	10
120	3.653	3.656	3	232	1.747	1.747	9
200	3.527	3.533	38	023	1.732	1.732	12
021	3.414	3.416	5	331	1.727	1.727	24
210	3.260	—	—	410	1.727		
121	3.073	—	—	042	1.707	1.707	19
201	2.996	2.997	95	203	1.669	1.669	12
002	2.842	2.841	38	051	1.636	1.636	9
211	2.828	—	—	420	1.630	1.631	24
220	2.719	2.718	14	151	1.594	1.594	10
012	2.696	—	—	223	1.554	1.555	5
130	2.640	2.640	84	133	1.539	1.539	14
102	2.636	—	—	242	1.536	1.536	14
031	2.546	—	—	332	1.528	1.528	36
112	2.519	2.518	100			1.499	14
221	2.453	2.453	71			1.476	5
131	2.394	2.395	59			1.450	5
022	2.366	—	—			1.433	31
310	2.267	—	—			1.424	9
122	2.243	2.242	21			1.421	24
230	2.215	2.215	84			1.392	5
202	2.213	—	—			1.382	9
301	2.173	—	—			1.375	5
212	2.142	2.142	67			1.354	7
040	2.135	—	—			1.343	9
311	2.106	—	—			1.320	3
320	2.060	2.059	13			1.310	12
140	2.044	2.044	29				
222	1.965	1.964	21				
132	1.934	1.935	29				
141	1.923	1.923	14				

Plus additional lines all with I ≤ 10

*All calculated *hkl*'s listed for $d_{hkl} \geq 2.100$Å. All $d_{hkl} \geq 1.500$Å are indexed. Indices and *d*(calc.) from the least-square analysis of X-ray powder data using the digital computer program of Appleman and Evans (1973).

**Data for material from Red Mountain, Mendocino County, California. X-ray diffractometer conditions are: Chart No. X-3839; Cu/Ni radiation, λ CuKα_1 = 1.54051Å; Si used as internal standard; scanned at ¼ ° 2θ per minute.

Figure 2. The forms shown are $b\{010\}$, $n\{120\}$, $m\{110\}$, $k\{210\}$, $M\{011\}$, $g\{0\bar{2}1\}$, $o'\{111\}$, $'o\{1\bar{1}1\}$, $p'\{121\}$, and $q\{\bar{2}11\}$. Crystals of this habit are elongate on *c* (also shown in Fig. 5). Smaller crystals of a simpler habit and elongate parallel to the *a* axis are also found at this locality. A typical crystal with this habit is shown in Figure 2 (upper right). Note that some of the disphenoids appear in complementary pairs: for these crystals, the forms are $o'\{111\}$ and $'o\{1\bar{1}1\}$, but others appear singly or with only an occasional face.

Vuagnatite from the Russian River cobbles occurs only as tiny crystals, up to 0.5 mm, showing only the right disphenoid $o'\{111\}$. The various habits of vuagnatite are shown in Figure 3; the single disphenoidal crystal (at the left) is from the Russian River No. 1 cobble. The other crystals are from Red Mountain; the two crystals with bipyramidal terminations are elongate parallel to *a*, the other two elongate parallel to *c*. Habits with elongation parallel to *c*, sometimes parallel to *a*, but never parallel to *b* are precisely in conformity with what would be expected in the space group $P2_12_12_1$ and with the orientation $c < a < b$ according to the rule of Donnay and Harker.

The appearance of satellite reflections from the (010) and (001) pinacoids in alternate quadrants only, during two-circle measurement, may be taken as an indication of twofold axes and lack of symmetry planes normal to the pinacoid faces.

X-RAY CRYSTALLOGRAPHY

Unit-cell data for vuagnatite from California are compared with those from Turkey (Sarp *et al.*, 1976) in Table 1. The unit-cell dimensions were obtained by least-squares refinement of the X-ray powder diffraction data given in Table 2.

OPTICAL PROPERTIES

The optical properties of vuagnatite, shown in Table 1, were obtained from X-ray oriented single crystals using a Supper spindle stage and sodium light. Vuagnatite typically is colorless, but some crystals at Rhea's original locality at Red Mountain are pale yellowish-brown. Under the microscope the color appears to be mottled, or to show "phantoms" or multiple "phantoms" (Fig. 6). Only one uniformly-colored crystal has so far been found. The unit cell dimensions of the colored crystals are essentially identical with those of the

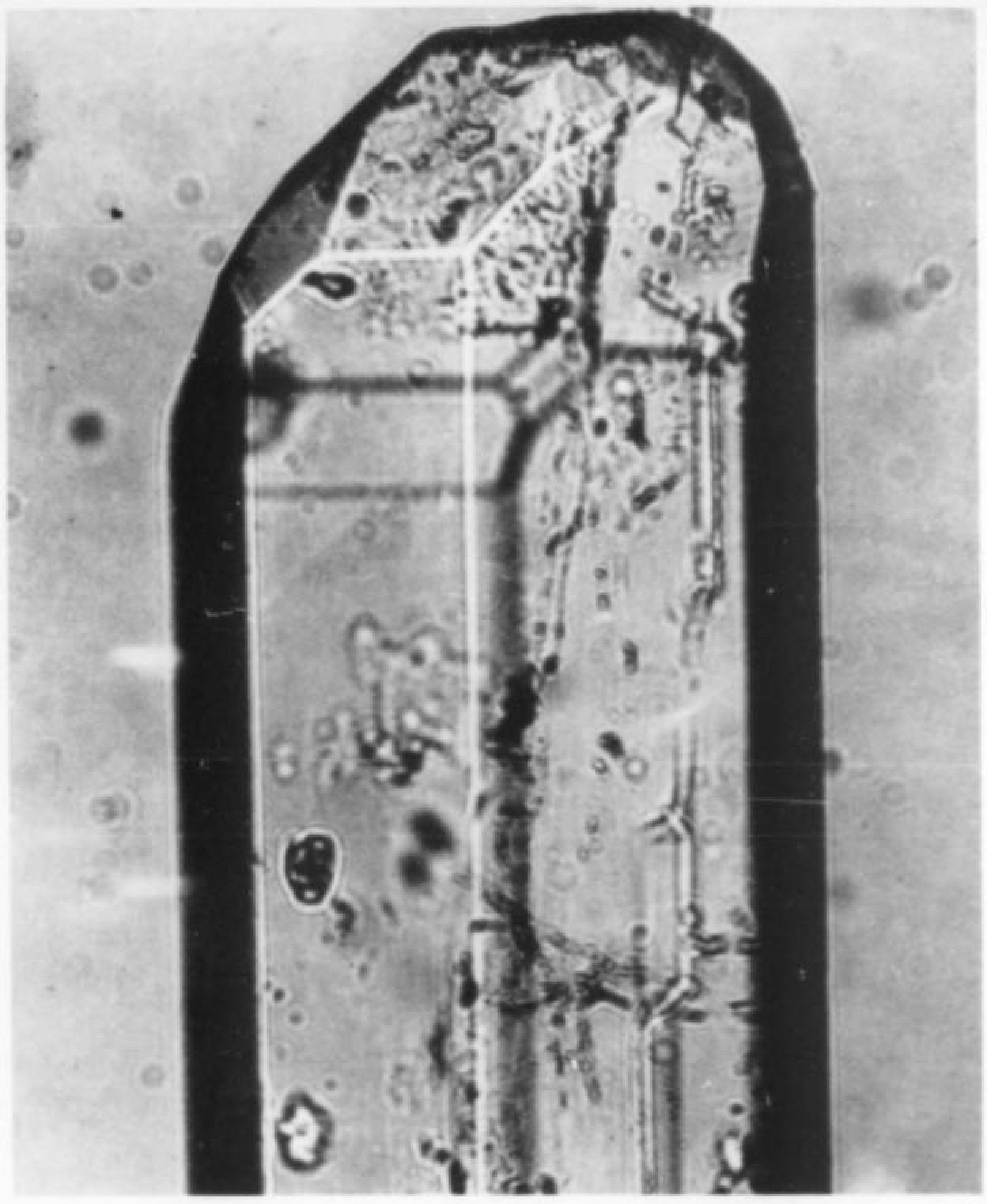

Figure 5. (left) **A prismatic crystal of vuagnatite elongated parallel to** ***c*****. The width of the crystal is 0.3 mm. (Red Mountain locality.)**

colorless crystals, but the indices of refraction are slightly higher: $\alpha = 1.704(2), \beta = 1.726(2), \gamma = 1.730(2)$.

The optical properties of vuagnatite may easily be confused with those of clinozoisite or low-iron epidote, depending upon the section seen, and the mineral may well have been overlooked until now for this reason.

CHEMISTRY

Crystals of vuagnatite from the Red Mountain and Russian River localities were microanalyzed with an ARL electron microprobe, giving the results shown in Table 3. The figures shown are the averages of two determinations for each crystal. The crystals were relatively homogeneous except for one (Table 3, No. 3) at the Russian River locality that contained inclusions of diopside. Traces of Mg, Fe, and Mn determined spectrographically in vuagnatite from this locality are probably also due to included diopside.

When heated slowly above 650°C, vuagnatite loses water gradually and becomes slightly cloudy. The X-ray powder diffraction pattern of material heated to 665°C shows a few additional lines due to gehlenite. At 725°C, essentially all of the 5.11 percent of water has been driven off. The crystals are porcelaneous at this point, but give no indication of fusion and the X-ray pattern still shows a trace of vuagnatite. At 985°C there are only X-ray powder lines corresponding to gehlenite and anorthite present in a rotation photograph. However, vuagnatite does not melt at this temperature and would not be expected to do so until the ternary eutectic point at 1266°C is reached.

TABLE 3. Microprobe analyses of vuagnatite.

	1	*2*	*3*	*4*	*5*	*6*
Ca	22.10	22.20	22.16	22.13	22.26	22.75
Al	15.15	14.96	15.03	15.24	15.01	15.32
Si	16.15	16.20	16.04	16.10	16.16	15.94

Analyst: Fraser Goff, U.S. Geological Survey. Data in weight percent.

1 - 3: Crystals from the Russian River locality.
4 - 5: Crystals from the Red Mountain locality (No. 1).
6 : Calculated composition (neglecting H_2O) for $CaAlSiO_4(OH)$.

However, when vuagnatite is heated rapidly (as over a Meeker burner), some of the water is entrapped and the mineral fuses readily to a frothy glass with $n = 1.608$ and with crystalline inclusions of gehlenite and anorthite.

Vuagnatite is insoluble, or only very slightly soluble, in hot aqua regia but, in a way similar to grossular and idocrase, gelatinizes with acid after fusion before the blowpipe.

It is interesting to note that vuagnatite has not been found as a phase in studies of the CaO-Al_2O_3-SiO_2-H_2O system (such as those of Huckenholz *et al.*, 1975; and Shōji, 1974), but most of these have been conducted at higher temperatures and lower pressures than those at which vuagnatite might be expected to form. Structurally, vuagnatite is related to the conichalcite ($CaCuAsO_4(OH)$) group of minerals, but chemically it is the analog of datolite ($CaBSiO_4(OH)$).

Vuagnatite may not be an uncommon mineral and should be sought in rodingite assemblages. It would be especially fruitful to locate the outcrop sources of the Russian River cobbles.

ACKNOWLEDGMENTS

We appreciate having had the opportunity to read the paper of Halil Sarp, Jean Bertrand, and Elizabeth McNear in advance of its publication, and to have exchanged information with them regarding the occurrences of vuagnatite. We are indebted to J. Hampel, University of California, Berkeley, for the photography. We wish to thank the U.S. Bureau of Land Management for helpful information on the Red Mountain area.

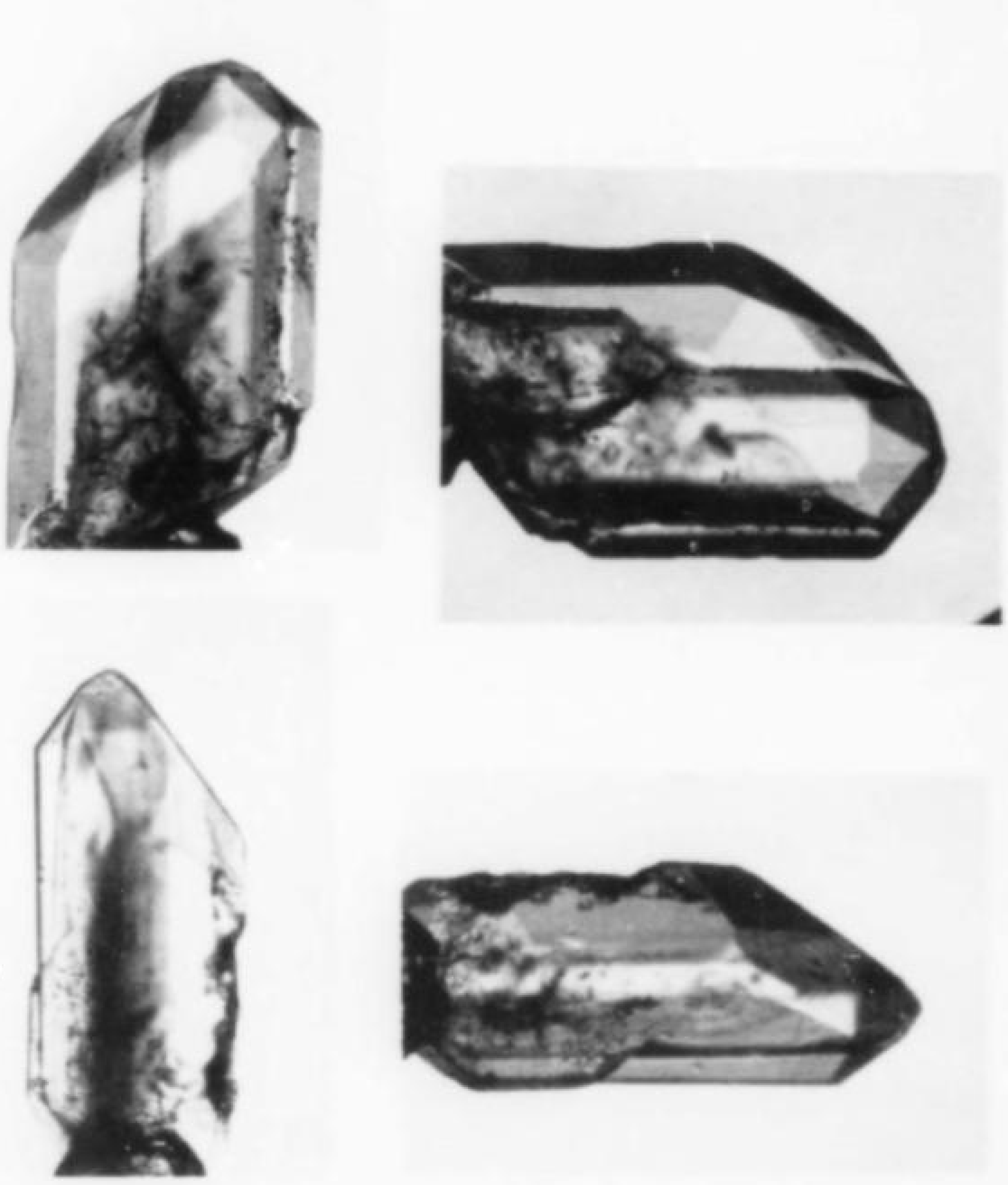

Figure 6. (right) **Various views of a pleochroic crystal from the Red Mountain locality. A "phantom" is visible within the crystal. The crystal is elongated parallel to** ***c*****. These views are in the** ***a-c*** **plane (top photos) and** ***b-c*** **plane (bottom photos). The vibration direction of the polarizer is vertical in all four photos. The width of the crystal, as seen in the bottom photos, is 0.3 mm.**

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HYDROBORACITE

from the AMARGOSA DESERT, EASTERN CALIFORNIA

by Robert L. Countryman
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Los Angeles, California 90024

HYDROBORACITE ($CaMgB_6O_{11}\cdot 5H_2O$), in the form of radial clusters of acicular crystals up to 5 cm long, has been identified from the Terry borate mine, Inyo County, in eastern California. It is associated with colemanite, calcite, phillipsite, analcime, chabazite, and clinoptilolite. The hydroboracite apparently formed through groundwater alteration of colemanite.

Figure 1. **Mining operation at the Terry pit: mine geologist C. Barker is directing a front-end loader into a rich colemanite horizon. The Terry mine is presently worked out and closed.**

Hydroboracite (**$CaMgB_6O_{11}\cdot 5H_2O$**) was first described from the Caucasus Mountains in 1883 (Palache, *et al*, 1951) and has since been reported from many of the borate localities throughout the world. It has now been discovered in the Amargosa desert at the Terry borate mine, located 7.5 km west of Amargosa (Death Valley Junction), Inyo County, California, and 123 km west of Las Vegas, Nevada. This new locality is believed to be the first report of hydroboracite in the Amargosa Valley borate area and only the second report of this rare mineral in large well-preserved crystals, the first being at the Thompson mine in Death Valley (Minette and Wilber, 1973).

The Terry deposit occurs within the Pliocene Furnace Creek formation described by McAllister (1973) as being composed of lacustrine mudstones and sandstones, interbedded massive tuffs, minor limestones, conglomerates, and altered fragmental basalts. Locally the strata encompassing the Terry deposit consist of pale olive-green calcareous mudstones with light grey limestone laminae, tan fine-grained tuffaceous sandstones, and white to tan tuffs. The borates are found within a lens-shaped limestone and clay horizon about 95 metres wide and varying up to 10.5 m in thickness. The horizon contains vuggy clusters of large (10 - 25 cm) interlocking radial colemanite crystals and minor accessory hydroboracite in a marly matrix. An irregular halo within the shales surrounding the borate horizon contains fracture fillings of ulexite and gypsum as well

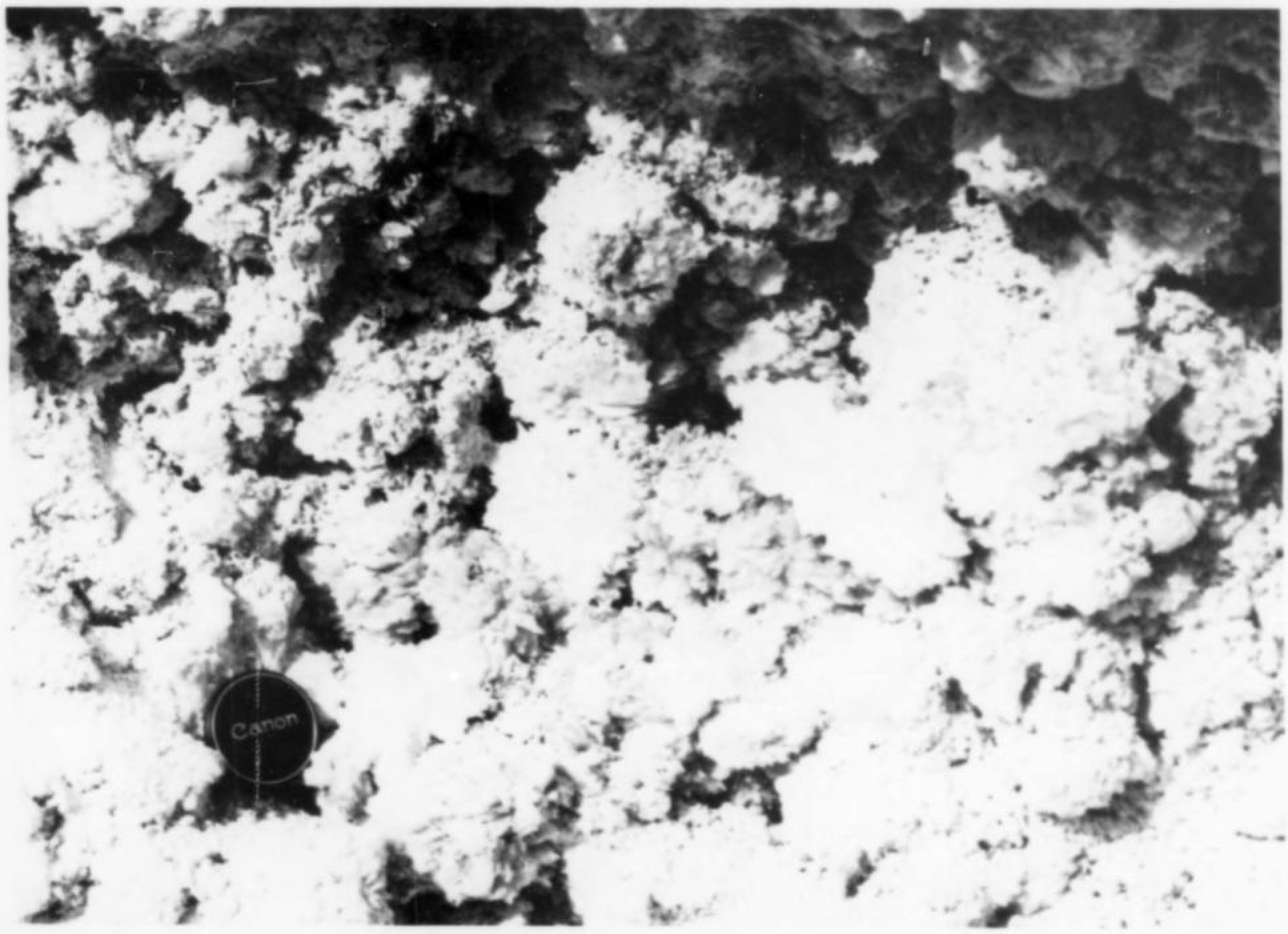


Figure 2. **Radial colemanite crystal groups *in situ* in the main borate horizon; radiating sprays of hydroboracite were also found in this zone. The lens cap is 5 cm across.**

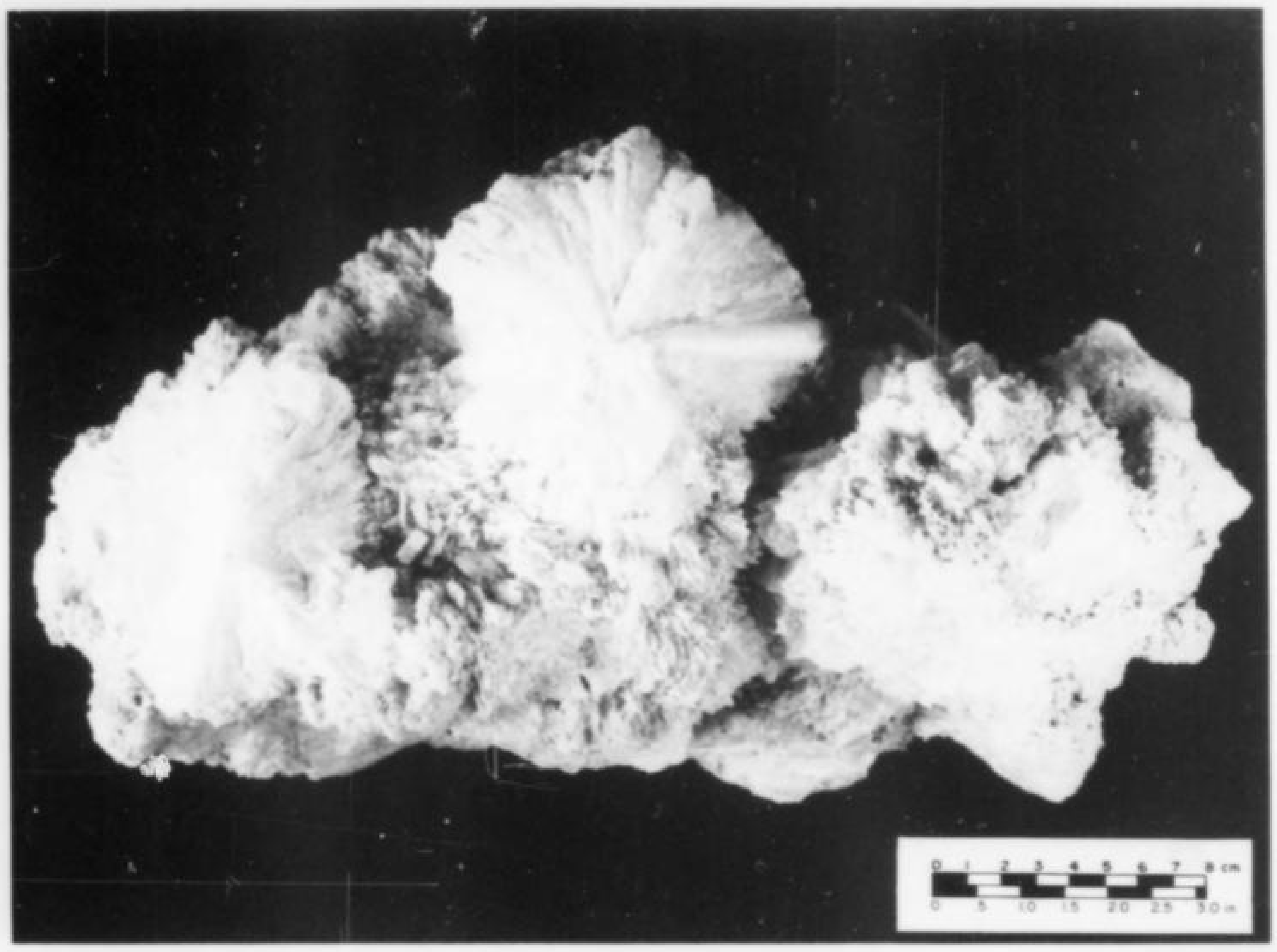
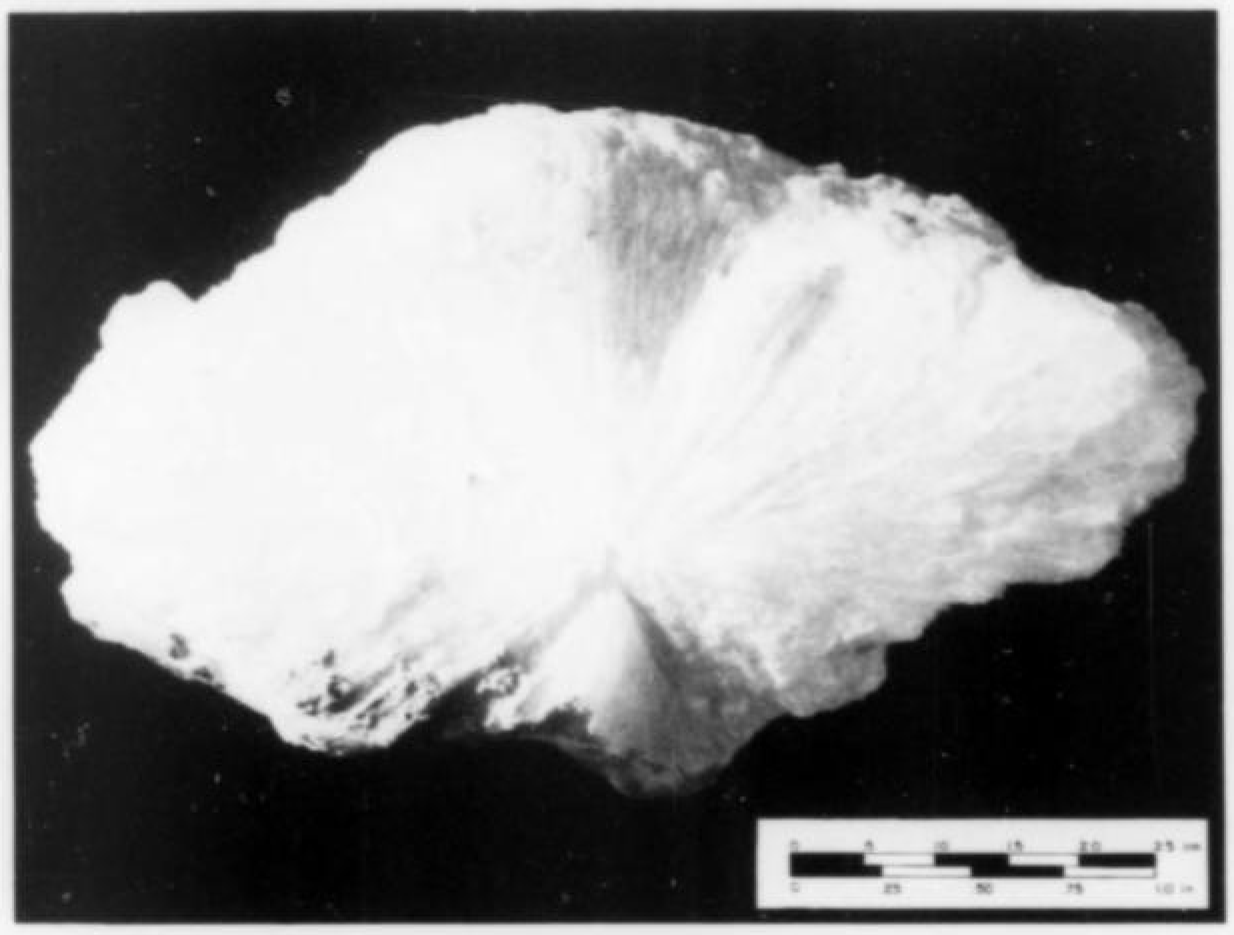


Figure 3. (left) **Large clusters of radial colemanite crystals on marly mudstone matrix. UCLA collection specimen number ML-86-1.**

Figure 4. (below) **Radial group of hydroboracite crystals, possibly pseudomorphous after colemanite. UCLA collection specimen number MS 1513A.**



as ulexite cottonballs along shale partings. A thin zeolitized tuff bed near the top of the horizon contains analcime, phillipsite, chabazite, and clinoptilolite.

Hydroboracite occurs in several forms at the Terry deposit. Drusy coatings and radiating sprays of acicular crystals, some up to 2-3 cm long, are found within vugs between the interlocking colemanite crystals. Large radial clusters of acicular hydroboracite crystals up to 5 cm long occur in a massive marly matrix and are very similar in appearance to the radial habit of colemanite. Microscopic hydroboracite can be found in association with colemanite and secondary calcite at the highly weathered edges of the deposit. The crystals are generally clear to white and translucent, with a silky luster and a hardness of 2-3. The hydroboracite sprays occur secondary to the radial colemanite crystals but are in turn frequently overgrown by small, clear, elongated colemanite crystals. At the edges of the borate horizon, both borates are weathering to calcite.

The occurrence of hydroboracite at the Terry deposit is apparently the result of a complex history of alteration. Christ, *et al.* (1967) indicate that a decrease in the activity of Ca or an increase in that of Mg would favor the formation of hydroboracite at the expense of colemanite, whereas changes in the activity of H_2O, presence of other salts, and temperature variations probably would have significantly less effect. Groundwater studies (Haff, 1973) indicate that the portion of the Amargosa desert containing the Terry deposit presently has a significantly higher Mg/Ca ratio than does the remaining portion of the desert. Based upon this information, an alteration history for the Terry deposit can be envisioned as follows. After burial and dehydration of a primary borate to colemanite, the Terry deposit was uplifted to its present position near the surface and subjected to groundwater alteration in a relatively Ca-poor and Mg-rich environment. Conversion of colemanite to hydroboracite and the precipitation of hydroboracite within vugs then resulted. Subsequent minor fluctuations in the activities of Ca and Mg due to changes in the groundwater chemistry could then cause oscillations between colemanite and hydroboracite precipitation and result in growth of the small colemanite crystals on the radial hydroboracite and the precipitation of the drusy and microcrystalline hydroboracite.

All mineral identifications used in this report were obtained through X-ray powder diffraction methods. The samples were ground to less than 63 μm, mounted on a glass slide, and X-rayed on a Phillips powder diffractometer using Cu $K\alpha$ radiation and a graphite monochromator. The patterns produced were compared against ASTM values and patterns of known samples.

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I would like to state my appreciation to the staff and management of Tenneco Mining Inc., particularly to Charles Barker, mine geologist at the Terry pit, for enlightening discussions and permission to sample the mine. I would like to extend my appreciation to W. Dollase (UCLA) and W.I. Gustafson (Calif. State Univ.:Northridge) for reviewing the manuscript and also to Lowell Weymouth (UCLA) for his excellent mineral photography.

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A SELECTED BIBLIOGRAPHY OF CALIFORNIA MINERAL OCCURRENCES

by

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THE *MINERALS OF CALIFORNIA* SERIES

Since 1914, the California Division of Mines and Geology has published at approximately ten-year intervals a bulletin series entitled *Minerals of California*. These bulletins have listed, by county, significant mineral occurrences in the state. The data are supported by complete bibliographies of published sources.

The most recent issue in the *Minerals of California* series is *Bulletin **189***, authored by Joseph Murdoch and Robert W. Webb. The bibliography of this issue covers 115 pages. *Bulletin **189*** covers information available through December 1964. In 1969 the Mineral Research Society of California, a private organization, published a supplement to *Bulletin **189***, covering the years 1965 through 1968. (Copies of that supplement are available from the Mineral Research Society, 2051 Charlemagne Street, Long Beach, CA 90815.)

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Besides the *Bulletin* series the state Division of Mines and Geology has published since 1950 a *Special Reports* series. Many of the *Bulletins* and *Special Reports* carry significant information about mineral occurrences in the state.

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THE NATURAL GEOLOGIC PROVINCES OF CALIFORNIA

Over 600 mineral species have been identified in California. One of the primary reasons why this number is so large is the geologic and mineralogic diversity of the state's natural provinces, each of which has unique characteristics. Some of the more significant references for the mineralogically important provinces are listed below.

Klamath Mountains Province

ALBERS, J.P. (1966) Economic deposits of the Klamath Mountains. In *Geology of Northern California. California Division of Mines and Geology Bulletin **190***, 51-62. *See also bibliography* pp. 61-62.

Modoc Plateau, Cascade Range and Northeastern Great Basin Provinces

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Coast Ranges Province

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Lake Bed Deposits of the Great Basin and Mohave Desert Provinces

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Pegmatites of the Peninsular Ranges

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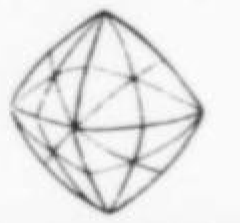

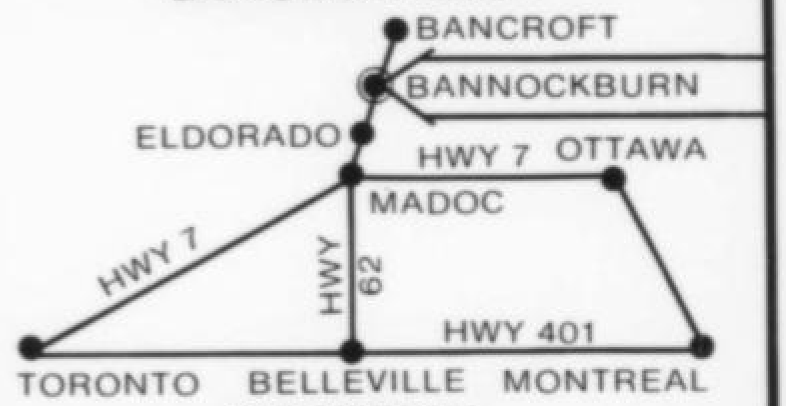

THE BEST OF
SAN DIEGO COUNTY

by Bill Larson
912 S. Live Oak Park Road
Fallbrook, California 92028

Almost all fine mineral collections are graced with mineral treasures from the pegmatite mines of San Diego County, California. This is perhaps not too surprising, considering that many of these mines were discovered in the late 1800's and total production of specimens is documented in the hundreds of tons. The best specimens that have been preserved make for an interesting discussion.

WITH the overwhelming and well-deserved success of the TSUMEB issue, a new standard of excellence has been set in mineral periodicals. To continue in this direction, the editor called me to discuss an upcoming California issue and to see what could be done along the lines of Charles Key's excellent article, "The Best of Tsumeb." The answer: nothing. No single mine in California could interest readers as does Tsumeb; however, what about several areas? What about "The Best of San Diego County"? I began to sift my memory and gather the opinions of long time San Diego County collectors, various dealers and several museum curators. The result is a collage of their opinions, summarized by myself, hopefully devoid of the typical rumored specimens (4-foot-long, flawless tourmaline?), lost specimens, or faked specimens. Certain known specimens have been excluded because specific locality information has not been preserved through the years and could not be accurately inferred from their characteristics. Many other exceptional specimens no longer exist due to carelessness or (because several species are gem materials) the dreaded "crystal chopper." Apologies must be made to all the collections, both public and private, which have fine specimens from San Diego County and are not mentioned. However, this will be a problem inherent in all "best of" attempts; we hope reader response will enlighten us and add to our knowledge.

The decision as to which species to include for discussion was based upon specimens produced in San Diego County which compare favorably to very fine quality specimens of the same species produced at other famous localities around the world. That is not to say these are the finest in the world, but simply that these are of *very* fine quality (and in the case of elbaite, kunzite, morganite and spessartine, probably indeed the finest ever produced). This left us primarily with the pegmatite minerals (no one wants the finest San Diego chalcopyrite). I have further eliminated species that occur only as micromounts (San Diego County has the finest stewartite ever produced) as well as a few species not generally appreciated by specimen collectors (such as large, crumbling, altered lithiophilite crystals, undoubtably among the finest?!) and have come up with something over 100 specimens of fifteen species from twenty-one mines (or prospects).

The difficult problem of choosing the criteria by which to judge the finest is certainly open to debate. The individual must evaluate all specimens as to color, form, perfection, size, and that somewhat mysterious quality, aesthetics. I think it will become increasingly apparent as more "best" attempts are written that there is rarely a best single specimen which is obviously finer in all the critical features prized by connoisseurs. Rather, there will be several specimens all possessing a number of the criteria deemed necessary to be exceptional, which will share the elusive crown of "The Finest."

San Diego County consists of several general pegmatite districts: *Chihuahua Valley, Aguanga, Pala, Rincon, Mesa Grande, Ramona* and *Jacumba*. See the map on page 461 of this issue for the locations of these districts. These areas contain numerous mines and prospects, most of which will not be discussed here because they did not produce fine specimens or were never documented. In addition to these districts, I have included *Fallbrook* as a location since it has produced several specimens of note.

CHIHUAHUA VALLEY DISTRICT

Blue Chihuahua mine

Herderite. Four outstanding examples of blue-green, gemmy herderite are the top specimens: **1.** a perfect, twinned, 1¾ x ⅝-inch herderite on a 2 x 2-inch microcline matrix (E. Swoboda collection, Beverly Hills, California); **2.** an unusual gem herderite crystal 1¼ x 1 inch, capped scepter-like, with opaque white herderite (J. Scripps collection, San Luis Rey, California); **3.** a combination of herderite and topaz, 2 x 1 inch (B. Bartsch collection, Pasadena, California); **4.** a perfect, gemmy single crystal 1½ x ¾ inch (B. Larson collection, Fallbrook, California) (Fig. 1).

Tourmaline. Numerous bright single crystals and matrix specimens of schorl were produced. The finest is a "V" shaped inter-

Figure 1. **HERDERITE, blue-green, ¾ x 1½ inches, from the Blue Chihuahua mine, Chihuahua Valley District, California. Collection of B. Larson; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

growth in which the longest tourmaline crystal measures 1½ x ¾ inch (J. Scripps collection).

Topaz. Numerous single crystals were produced, perhaps many equivalent, but one 1 x 1½-inch white single with a complex termination stands out (B. Bartsch collection).

AGUANGA DISTRICT

Emeralite (Ware) mine

Tourmaline. Elbaite from this locality is noted for an exquisite sky-blue color, locally called emeralite. The finest example is a beautiful 1½ x 2-inch multicolored crystal grading from the sky-blue to pink (M. Ware Van de Velde collection). **Topaz.** The finest example consists of two medium-blue, intergrown crystals, 3 x 3 x 4 inches (M. Ware Van de Velde collection). Another fine crystal is a 3 x 3 x 2 inch single (in the California Institute of Technology collection, Pasadena).

Aquamarine. Aquamarine was rarely produced at this locality, however, one exceptional crystal is certainly worthy of note: an etched blue-green gem crystal 3¾ x 1 inch (J. Scripps collection).

PALA DISTRICT

Stewart mine

Tourmaline. Production for the mine's history is several tons, so numerous crystals are known. The largest is an incredible 10 x 4-inch rubellite with cleavelandite (S. Singer collection, New York). The finest are three specimens produced in one pocket in 1969. These are each approximately 4 x 1 inch with lepidolite association (E. Swoboda, B. Larson (Fig. 3) and J. Barlow, Appleton, Wisconsin, collections). The best miniature is a 1¾ x ¾-inch blue tourmaline on white cleavelandite (B. Schneider collection, Poway, California). The most unique specimens are three crystal sunbursts of gem-pink tourmaline about 1¼ x 1 inch each (San Diego Museum of Natural History collection, San Diego, California).

Spodumene. This mineral is only rarely encountered at the Stewart mine. Two exceptional examples of gem-quality light yellow spodumene are known. The finest is a 2½ x 3½-inch spodumene on a 5 x 6-inch piece of pocket matrix with pink tourmaline (E. Swoboda collection). The second best is a 2 x 3-inch spodumene on a 3 x 4-inch piece of pocket matrix (J. Barlow collection).

Morganite. Numerous single crystals and matrix specimens were produced, however, few are of fine quality. The finest is a 1 x 1¾-inch peach-colored morganite on a 2 x 3-inch matrix (B. Bartch collection). Another fine piece is a 1¾ x 1¼-inch light peach-colored morganite perched on a 2 x 1 inch pink tourmaline (E. Swoboda collection).

Stibiotantalite. Extremely rare, the finest specimen is a 1 x 1-inch dark brown crystal on a 2 x 3-inch piece of pocket matrix (D. Wilber collection, Carson City, Nevada).

Tourmaline Queen mine

Tourmaline. This mine has certainly been one of the largest tourmaline producers in San Diego County. Numerous specimens are incredible (more than slight prejudice demonstrated here since the author is co-owner of the mine). The finest specimens from production preceding Pala Properties' re-opening in 1971 are in the Harvard University collection, Boston and the British Museum of Natural History collection, London, England. The finest specimens overall were mined in one pocket found in 1972. These are easily discerned because of a deep indigo-blue termination. Perhaps the finest of these is a specimen consisting of two 4½ x 2-inch tourmaline crystals flaring out of a 6 x 4-inch quartz crystal (E. Swoboda collection). Other equally major pieces include one in the Smithsonian collection, Washington, D.C., with three large tourmaline crystals on matrix, the so called "Candelabra" (pictured on the cover of the *Record*, vol. 6, no. 2, 1975), another with two large tourmalines on intergrown quartz crystals in the Canadian National Museum collection, Ottawa, Canada (Fig. 2), and one composed of two tourmaline crystals attached by a quartz crystal with a cluster of morganite mid-way on the largest tourmaline (see sketch in the Record, vol. 5, no. 4, p. 154) (B. Larson collection).

Morganite. Many small, fine morganites have been produced. The finest is a unique specimen consisting of a complex 2½-inch morganite crystal attached to a 5-inch tourmaline (K. Proctor collection, Colorado Springs) (see the sketch in his ad in this issue and the color photo on p. 218 of vol. 7, no. 5 of the *Record*). Another specimen of superb quality is a 2½-inch morganite crystal perched on a 3 x 3-inch cleavelandite matrix with associated small tourmaline crystals (D. Wilber collection).

Apatite. One perfect, 1 x 1-inch purple apatite is known (D. Wilber collection).

Spessartine. This mineral has been found only once at the locality; one pocket was recovered in 1974 with orange spessartine similar to those produced in Ramona, California. The finest is a 1-inch gemmy orange spessartine on a 1 x 2-inch schorl crystal (D. Wilber collection).

Tourmaline King mine

Tourmaline. This mine has been another major producer of tourmaline; many of the large tourmaline singles found in the early 1900's were from this mine. The finest specimen is the

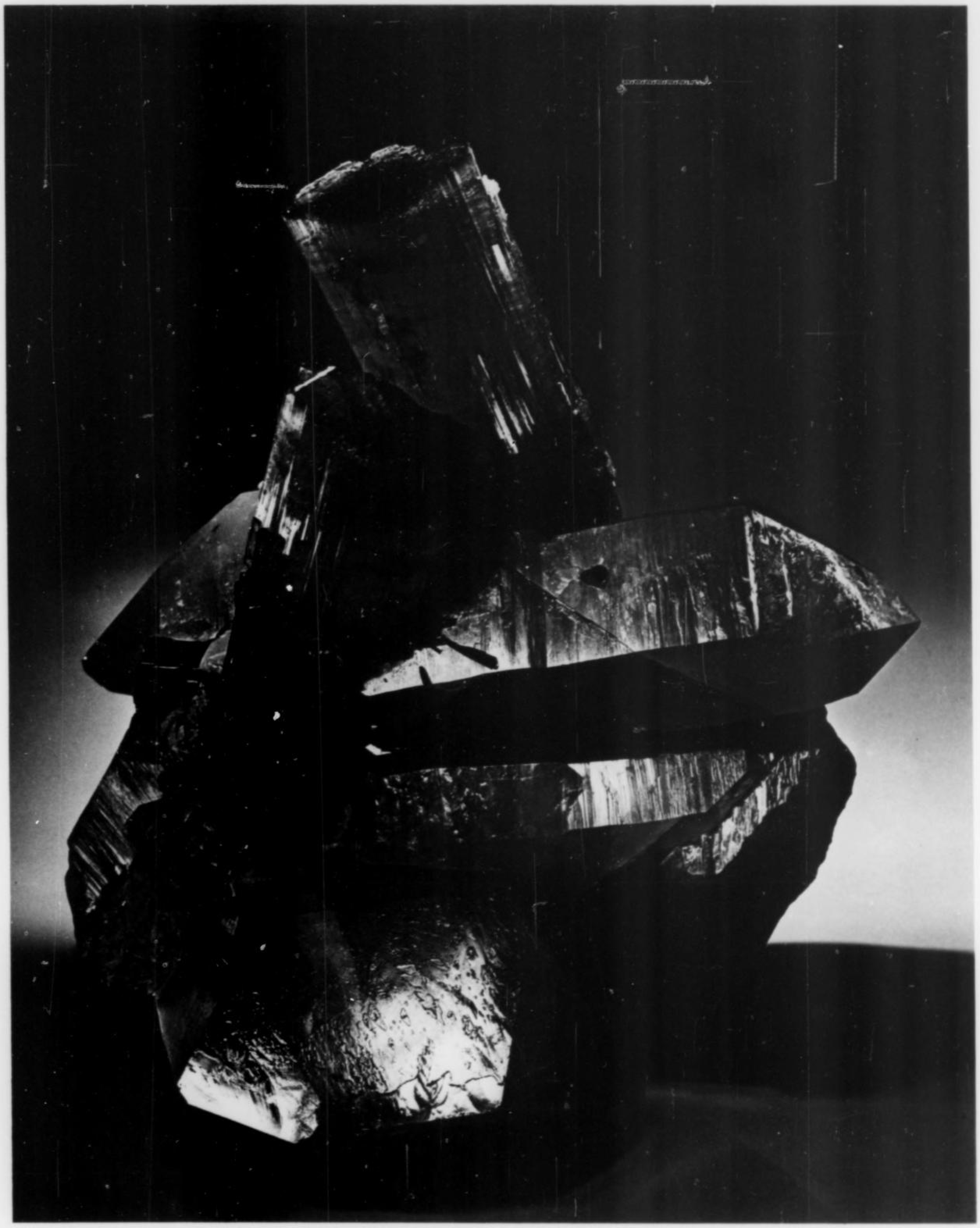

Figure 2. **ELBAITE tourmaline on quartz, about 10 inches tall, from the Tourmaline Queen mine, Pala District, California. Collection of the Canadian National Museum, Ottawa, Canada; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

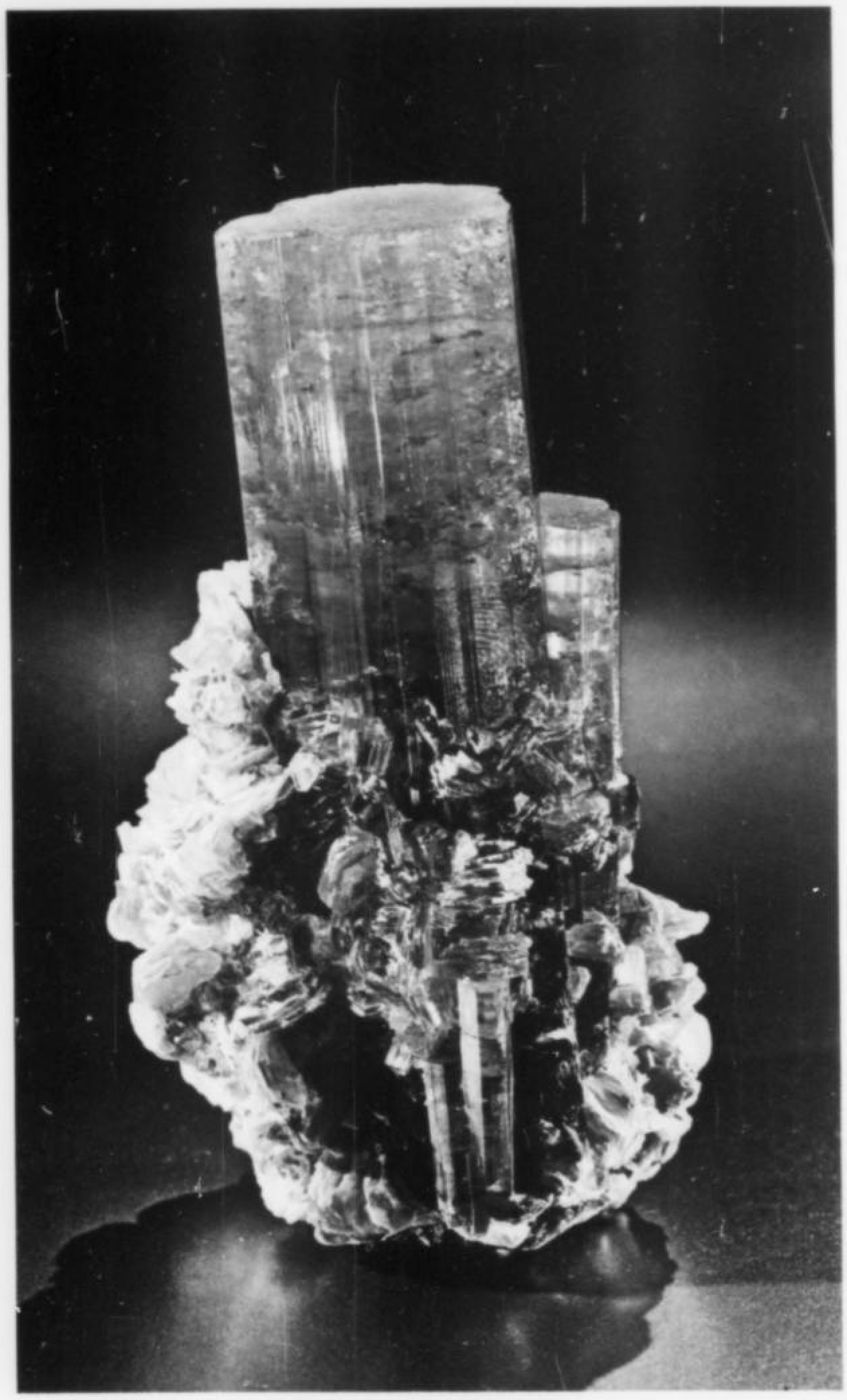

Figure 3. **ELBAITE tourmaline with lepidolite, 1 x 4 inches, from the Stewart mine, Pala District, California. Collection of B. Larson; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

famous "Steamboat" in the Smithsonian Institution (cover of the *Record*, vol. 2, no. 4, 1971). It consists of two perfect tourmaline crystals, 6 x 2½ inches each, on a matrix of cleavelandite, and perched on a large double terminated quartz crystal over 1 foot long (for a view of the entire specimens see p. 171 of Peter Bancroft's *World's Finest Minerals and Crystals*, 1973). The second finest I have seen (that was certainly from the Tourmaline King mine) is an intergrowth of four large (approximately 5 x 2-inch) tourmaline crystals in the Vienna Natural History Museum collection. Numerous other fine examples from the Tourmaline King mine are in most museums. An exceptional over-all suite of tourmaline from this locality is on display at the San Diego Agriculture Building in San Diego. Note: the Fletcher mine was located on the same pegmatite and adjoins the Tourmaline King mine. Specimens produced from both mines are indistinguishable.

Morganite. This mine yielded a large production of crystals, but was poorly documented. The finest piece is a matrix specimen of lepidolite and cleavelandite, approximately 7 x 9 inches in size, studded with over five 1 to 2-inch-diameter morganite crystals (American Museum of Natural History collection, New York).

Columbite. Columbite is rarely recovered from this mine. The finest known specimen is a 1 x 1-inch complete crystal on a 2 x 2½-inch quartz crystal (J. Scripps collection).

Pala Chief mine

Spodumene. The finest crystals of kunzite produced anywhere, came from the Pala Chief. The finest crystals are the two rich purple, well-formed, flawless crystals kept in Harvard University's vault. The largest of these is approximately 11 x 3 x 1 inch. Numerous other extraordinary kunzite crystals are in major museums, notably the Musee au Jardin des Plantes, Paris, the American Museum of Natural History, and the Smithsonian Institution. The finest two pieces in private hands are the one in the T. Morris collection, Los Angeles, and the single crystal pictured in Kunz's *Gems, Jewelers' Materials and Ornamental Stones of California*, p. 80 (B. Larson collection) (Fig. 6).

Tourmaline. Somewhat overshadowed by the famous kunzite crystals, Pala Chief tourmalines include some of the finest colored red tourmaline known. The finest specimen is an ideal textbook matrix specimen consisting of a 6 x 3-inch tourmaline crystal attached parallel to a larger quartz crystal (American Museum of Natural History collection). Perhaps the finest single crystal is in the Musee au Jardin des Plantes. Many others are similar, notably, a fine single crystal 7 x 3 inches, in the American Museum of Natural History collection, and the fine 6 x 3-inch crystal in the Cranbrook Institute collection, Detroit, Michigan. In private hands the fine red single crystal, 6 x 3 inches, in the

Figure 4. **MORGANITE beryl on cleavelandite albite, 1½ x 2 inches, from the White Queen mine, Pala District, California. Collection of E. Swoboda; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

Figure 5. **KUNZITE spodumene, about 5 x 7 inches, from the Pala Chief mine, Pala District, California. Collection of B. Larson; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

Figure 6. **MORGANITE beryl, 3 x 4 x 5 inches, from the Himalaya mine, Mesa Grande District, California. Collection of B. Larson; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

D. Wilber collection is the finest. Another similar piece is in the collection of A. Kaplan, New York.

Morganite. Many fine morganites were produced, but locality information seems all but lost. The two finest that are known Pala Chief specimens are a fine 1 x 2-inch morganite on a 2 x 3-inch feldspar matrix (T. McKee collection, Scottsdale, Arizona) and a 1¾ x 1½-inch crystal on a small ball of lepidolite in the J. Scripps collection.

Aquamarine. Aquamarine was rarely produced at the Pala Chief mine. The finest specimen is a 1 x 1½-inch light blue aquamarine on a 2 x 3-inch plate of muscovite (San Diego Museum of Natural History collection).

San Pedro mine

Spodumene. The finest crystal is an 11 x 3½-inch single, light purple gem crystal of kunzite (C. Reynolds collection, Valley Center, California). This crystal was recovered from a pocket that produced 280 pounds of spodumene.

Aquamarine. A totally unprecedented specimen is an incredible intergrowth of two fine blue aquamarine crystals measuring 3 x 4 inches overall (California Institute of Technology collection, Pasadena, California).

Morganite. The finest is a 3 x 2-inch morganite on a 7 x 5-inch matrix (C. Reynolds collection). Another fine specimen is a 2 x 2-inch crystal on matrix (B. Harris collection).

White Queen mine

Morganite. Perhaps the finest morganite crystals produced anywhere, in terms of beauty and perfection, are from the White Queen mine. The finest of these is a specimen pictured on page 102 of Bancroft's *World's Finest Minerals and Crystals*, a 1½ x 2-inch gemmy pink morganite on cleavelandite matrix (E. Swoboda collection) (Fig. 4). Other fine examples are in many collections, notably the Smithsonian collection and the N. Dawson collection, San Marcos, California. The finest miniature recovered is a perfect hexagonal prism almost 1 inch across on a cleavelandite plate 1½ x 2 inches (J. Scripps collection).

Cleavelandite. Although cleavelandite (platy albite) is a mineral usually not attractive enough for display collections, cleavelandite found in the White Queen is in the form of snow-white bladed aggregates which are quite beautiful. Many fine specimens were recovered; perhaps the finest is a 4 x 7-inch ovoid cleavelandite group (B. Harris collection).

Quartz. The quartz crystals produced in the White Queen mine are not attractive from the outside. These crystals are rough, corroded, clay-encrusted, and often grow to crude, large sizes (2 to 3 feet). However, when cut in half and polished, they reveal some of the most beautiful inclusions ever exhibited in quartz. The quartz is gem quality and all along the crystal faces is included red montmorillonite, manganese oxides, lithiophyllite and other minerals giving the impression of an undersea garden. Many specimens were so treated, the finest of which is a crystal cut in half down the *c* axis and approximately 16 x 10 inches in size (N. Dawson collection). Admittedly, these are not true mineral specimens since they require minor lapidary work, but readers have always been subjected to authors' prejudices.

Vandenberg mine

Kunzite. The Vandenberg mine has been a major producer of kunzite. The finest pocket was recovered by George Ashley. This pocket produced 130 pounds of fine, dark purple, gem-quality kunzite crystals. The finest preserved crystal is in the Smithsonian collection and measures approximately 5 x 2 x 1 inch.

Figure 7. **SPESSARTINE garnet crystal, about ¾ inch, on matrix with schorl, from the Hercules mine, Ramona District, California. Collection of D. Wilber; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

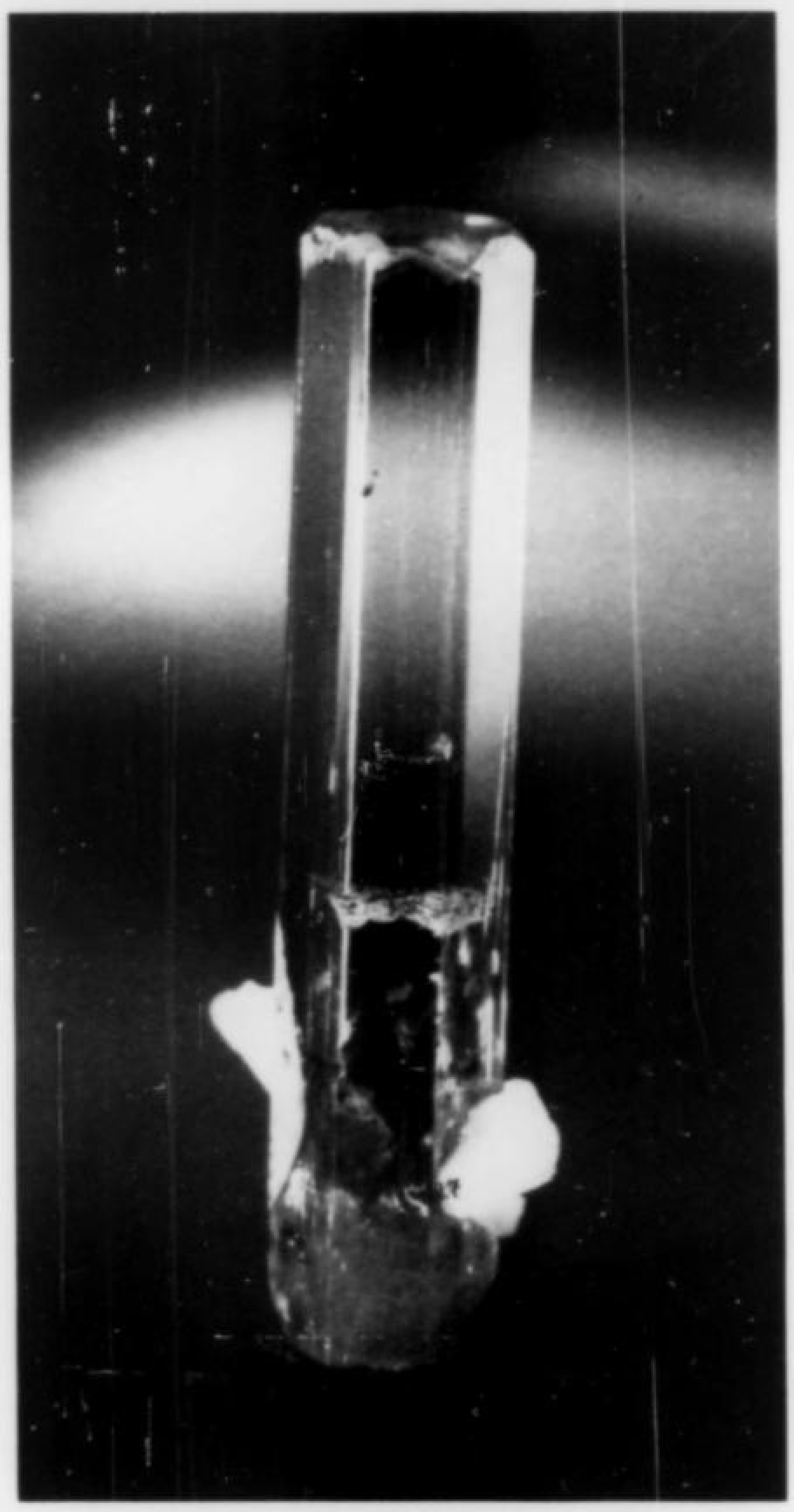

Figure 8. **AQUAMARINE beryl, pale blue, 2 inches tall, from the Mack mine, Rincon District, California. Collection of D. Wilber; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

quality kunzite crystals. The finest preserved crystal is in the Smithsonian collection and measures approximately 5 x 2 x 1 inch.

Morganite. Many fine small morganites have been produced from this locality. One specimen stands out as easily the finest. Discovered in the 1960's by the Norman Dawsons and nicknamed "The Miner's Lamp," this specimen is a perfect hemisphere of cleavelandite, approximately 10 inches in diameter, with one hexagonal morganite almost 4 inches in diameter perched on its center (Smithsonian collection).

Quartz. Unlike most other mines in the Pala District, the Vandenberg mine produced beautiful quartz crystals. Light yellow, complex, and reminiscent of Swiss pieces, the finest may be a 10 x 4-inch transparent crystal (J. Scripps collection).

Elizabeth R mine

Morganite. A small number of fine, etched morganite crystals have been recovered by R. Reed of El Cajon, California, during the past several years. Fine examples include: **1.** a 6 x 4-inch quartz and mica matrix with two 1½ x 1-inch peach-colored morganite crystals (B. Magee collection, Oceanside, California); **2.** an 8 x 10-inch quartz and mica matrix with two 1½ x 1-inch peach-colored morganite crystals (Los Angeles County Museum of Natural History collection, Los Angeles, California); **3.** a 3 x 2½-inch single (unetched) hexagonal gemmy prism (R. Reed collection).

FALLBROOK

No actual mines exist in the town of Fallbrook itself, however, numerous amateur mineral collectors have dug large prospects in conjunction with various local building and road construction projects.

Axinite. While many small crystals have been recovered, one incredible specimen is known. This piece is a complete 2 x 1½ x ⅜-inch rich plum-colored gemmy crystal with several small epidote crystals attached (Z. MacAnear collection, Fallbrook, California).

Quartz. Numerous smoky quartz pockets have been recovered. Two very different pieces stand out as the finest: **1.** a perfect 6½ x 2-inch light smoky gem crystal with large trapezohedral faces which give it an interesting termination; **2.** a very black, large, 12 x 6-inch tapered smoky quartz crystal with small epidote crystals encrusted on the prism faces (B. Harris collection).

RINCON DISTRICT

Mack mine

Aquamarine. Small vugs are commonly found in the footwall of this pegmatite, which contain flawless light blue aquamarine crystals. These crystals are usually from ½ to 1½ inches in length with a few notable exceptions. The two finest gem singles are: **1.** a 2 x ¼-inch flawless, light blue, single terminated crystal with cleavelandite attached near the base (D. Wilber collection) (Fig. 8); **2.** an equally fine single 2¼ x ¼-inch gem doubly terminated specimen (J. Scripps collection). Another fine specimen is a 1-inch gem aquamarine sticking out of a small matrix of white

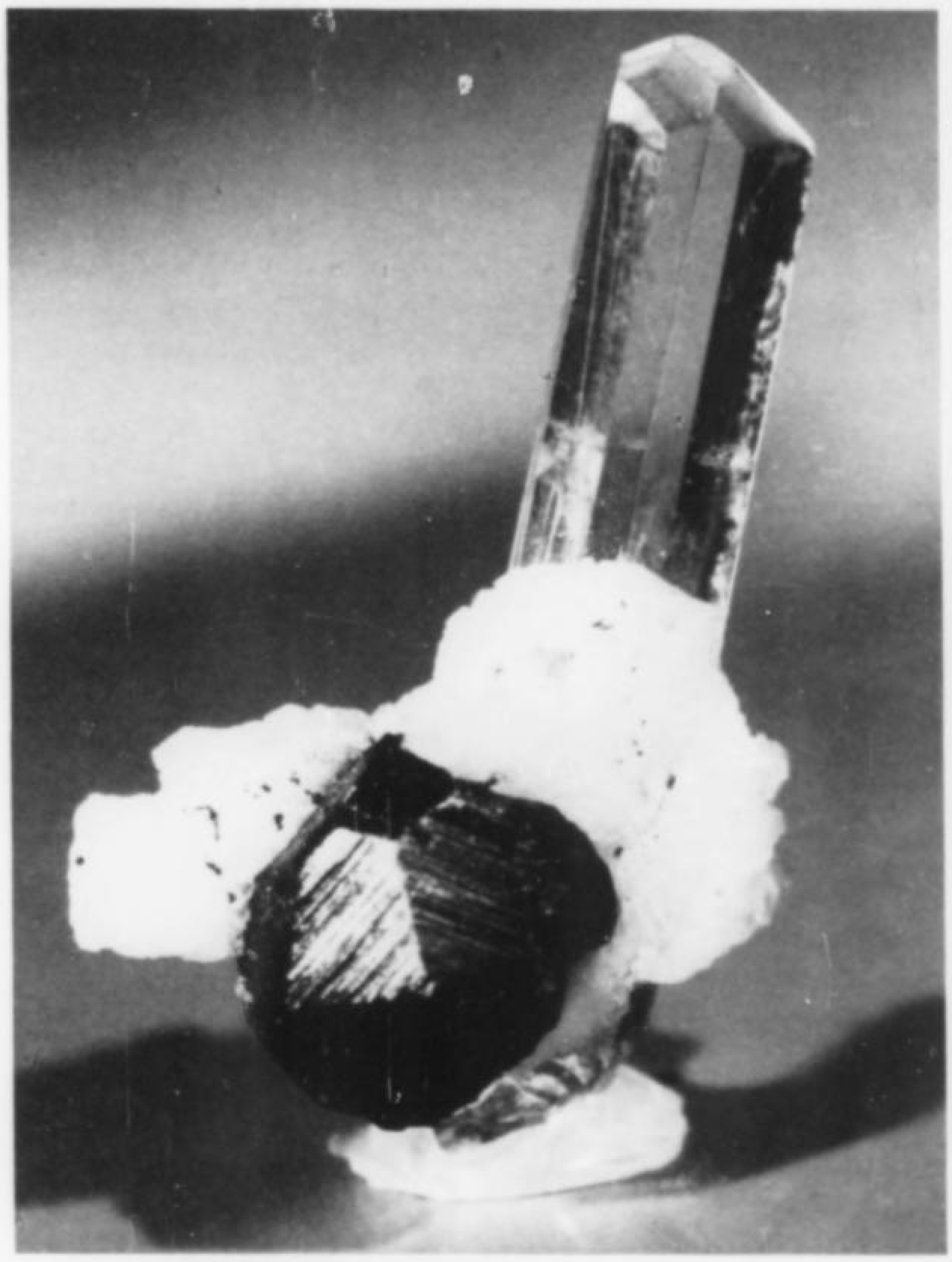

Figure 9. **AQUAMARINE beryl, pale blue, 1 inch tall, on white cleavelandite with a ⅜-inch crystal of gemmy red spessartine, from the Mack mine, Rincon District, California. Collection of B. Larson; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

cleavelandite with a ⅜-inch gem-red spessartine formed at the base of the aquamarine (B. Larson collection). (Fig. 9).

Clark mine

Apatite. One large 3 x 2-inch cluster of four deep blue apatite crystals, lightly dusted with muscovite crystals, is known from the Clark mine (J. Scripps collection).

Aquamarine. From near the main pegmatite and on the Clark claim, some aquamarine crystals larger in diameter than those produced in the Mack mine have been found. These are fine hexagonal prisms but are not of gem quality. Perhaps the finest is a 1½ x ¾-inch light blue aquamarine on a 6 x 4-inch quartz, mica and microcline matrix (B. Magee collection). Other fine specimens are in the C. Reynolds, B. Harris and J. Scripps collections.

Quartz. Numerous quartz crystals have been taken from the Clark mine, including one which weighed about 100 pounds and was cut into a flawless 6-inch sphere. The finest specimen known is a transparent, 8 x 3½ inch, perfect smoky crystal (N. Dawson collection).

Steven's Ranch

Titanite. A unique specimen for San Diego County was discovered in a small quartz-epidote vein. A perfect 1¾ x 1¼-inch titanite crystal was recovered among several smaller titanite crystals (D. Wilber collection).

MESA GRANDE DISTRICT

Himalaya mine

Tourmaline. Attempting to isolate the finest tourmaline from the Himalaya mine is folly, considering that the mine has yielded the largest production of any single locality in North America (some 90 tons of elbaite). Many extraordinary specimens exist. The most popular and unusual specimen is a cluster of four crystals, the main crystal being 3½ inches long with the other three attached at the top of the main crystal (Fig. 10). All crystals are doubly terminated and bi-colored. This cluster has been featured on the cover of the *Lapidary Journal*, June 1972: *Mineral Digest*, Vol. 7, and *Rock and Gem*, June 1977 (B. Larson collection). It was also pictured in color in the *Record*, vol. 7 no. 5, p. 236. The finest single is a limegreen and pink bi-colored 7 x 1½ -inch doubly terminated tourmaline (D. Wilber collection). One of the finest large matrix specimens is a 7 x 5-inch specimen in the Los Angeles County Museum of Natural History collection. The finest small matrix specimen is an incredible 5 x 1-inch tourmaline attached to a 3-inch quartz crystal with two minor tourmaline crystals (Smithsonian collection). Most major collections have examples from this locality.

Morganite. The morganite crystals from the Himalaya mine are unique in that they are beautifully etched, peach-colored crystals. The finest specimen is a 5 x 4 x 3-inch gem-quality crystal (B. Larson collection) (Fig. 6). Other fine examples are in the California Institute of Technology, B. Harris and D. Wilber collections.

Apatite. Beautiful pink apatite crystals are associated with tourmaline pockets found in certain portions of the Himalaya mine. Numerous fine crystals exist, however, many have been ruined since they fade rapidly to an unattractive white in sunlight. Among the finest is a 1¾ x ⅜-inch doubly terminated crystal attached to the top of a 1½ x 1-inch green tourmaline (J. Scripps collection).

Cassiterite. This mineral is rare at the Himalaya mine but beautifully formed small crystals are known. The finest by far is a ⅝-inch bright black crystal on a 1½ -inch green tourmaline crystal, pictured in Foord's article on the locality in this issue (B. Harris collection).

Hambergite. Although rarely found at this mine, the few that have been recovered are fairly similar all being approximately 1 x ½ -inch translucent white single crystals in the following collections: Los Angeles County Museum of Natural History, San Diego County Natural History Museum, B. Harris, J. Scripps, and B. Larson, to name a few.

Stibiotantalite. Very rare, fine, small single crystals are known from the Himalaya mine among advanced mineral collectors. Perhaps the finest are 2 x 1-inch single crystals in the Harvard University collection. Others are found in most museums. Two outstanding, extremely sharp, 1-inch-plus single crystals are in the D. Wilber and B. Harris collections.

Lepidolite. Few good lepidolite specimens were recovered or preserved out of the enormous quantity of lepidolite mined. The finest is a 2 x ¾ -inch rich purple gem crystal on a 5 x 4-inch tourmaline and quartz matrix (J. Scripps collection).

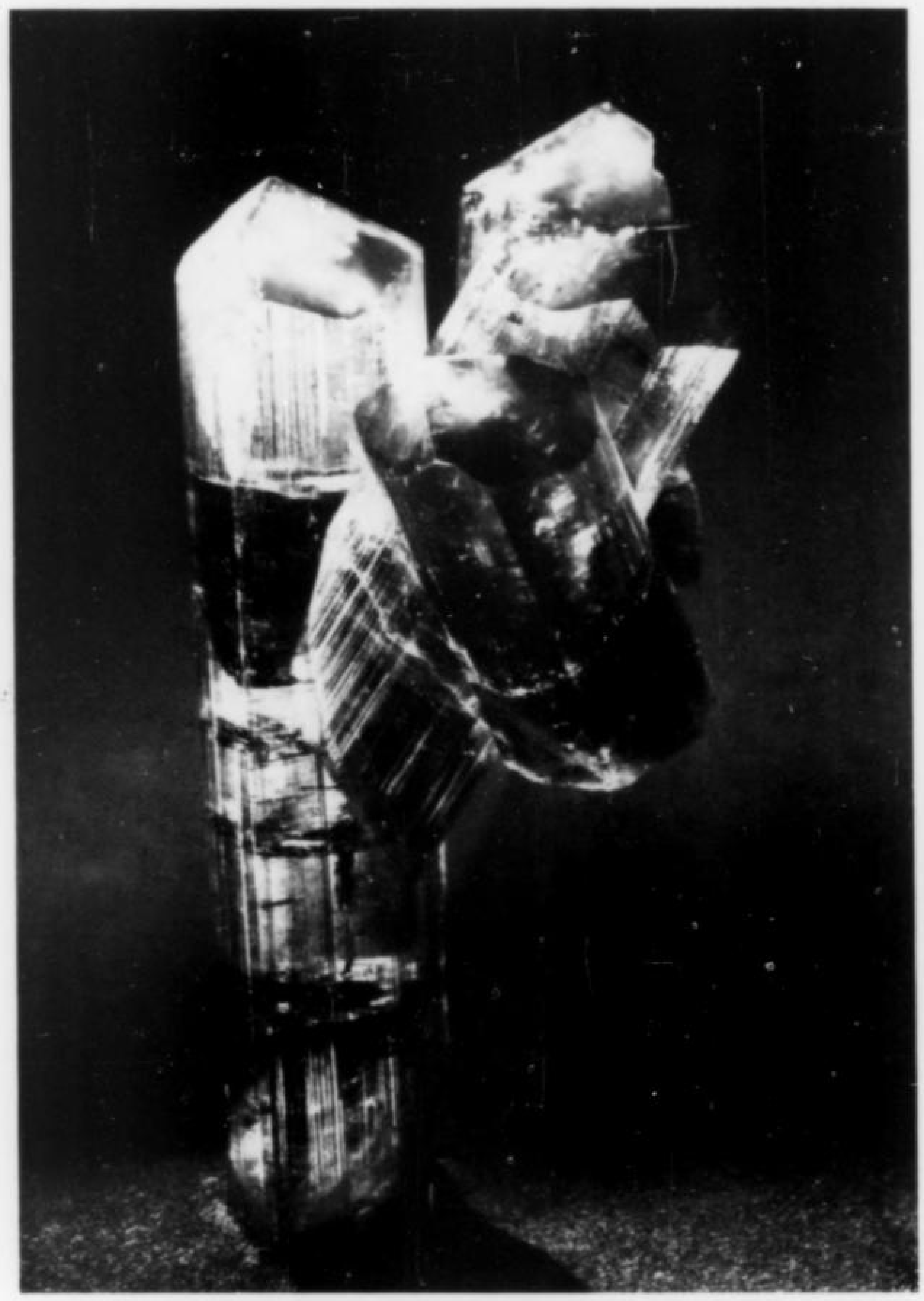

***Figure 10.* ELBAITE tourmaline, green with red tips, 3½ inches tall, from the Himalaya mine, Mesa Grande District, California. Collection of B. Larson; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

Microcline. While not a showy mineral, those recovered at the Himalaya mine are exceedingly sharp, fine crystals. Also, many of these are well-formed twin crystals, making these specimens more interesting for collectors. The finest suite is in the B. Harris collection, consisting of one 4 x 5-inch manebach twin, one 3 x 6-inch baveno twin, and one 3 x 5-inch carlsbad twin Another fine suite is in the San Diego County Museum of Natural History.

Esmeralda mine

Tourmaline. Fine dark blue tourmaline crystals were encountered with morganite crystals, however, poor documentation has lost most of these to locality collectors. The finest known tourmaline is a specimen with two 3 x ⅜-inch gem-quality blue tourmaline crystals attached to a 2 x 1-inch quartz crystal (L. Renge collection, Fresno, California).

Cota mine

Tourmaline. Fine, sharp, bright schorl crystals are known from this locality. The finest is a 3 x 1-inch single crystal with cleavelandite attached to the base (B. Larson collection). Another similar specimen is in the D. Wilber collection.

RAMONA DISTRICT

Little Three mine

Tourmaline. Known for numerous "slugs" of dark green tourmaline, the Little Three has produced, in the last year (1976), the finest tourmaline (and topaz) specimens in its history. The finest is an incredible 9 x 7-inch matrix specimen of cleavelandite and quartz with two 3 x 1½-inch tourmaline crystals perched on top and, for added impact, two intergrown 2-inch bluish topaz crystals attached on one end (L. Spaulding, Jr. collection, Ramona, California). Other large, fine, green tourmaline specimens are in the T. Morris, D. Wilber, J. Scripps and B. Harris collections, to name but a few. A unique specimen of yellow-green tourmaline 4 x ¾ inch in size and covered with many micro topaz crystals is in the D. Wilber collection. The finest miniature is a 2 x ⅜-inch flawless yellow and green bi-colored crystal in the G. Ashley collection, Pala, California.

Topaz. The Little Three mine is famous locally for the production of light blue topaz crystals. Certainly one of the finest is the specimen mentioned above under tourmaline. Another superb matrix piece is a 14 x 10-inch cleavelandite ball with a flawless 2½-inch topaz crystal attached (J. Scripps collection). Yet another fine specimen is a 5 x 4-inch cleavelandite and quartz matrix piece with three gem topaz crystals attached; the largest topaz crystal measures 1¾ inches (C. Larson collection, Fallbrook, California). These matrix specimens are similar to the famous Ural Mountains specimens. One fine, single topaz crystal is actually an intergrowth of two singles measuring 5 x 3 inches overall (L. Spaulding, Jr. collection). Perhaps the finest miniature is a 1½ x 1-inch gem crystal with attached cleavelandite (B. Larson collection) (Fig. 11).

Lepidolite. Associated with the topaz-tourmaline pockets at this locality are some of the finest lepidolite specimens in the world. Several specimens stand out; perhaps the finest is a 10 x 9-inch cluster of transparent to translucent lepidolite crystals, each up to 2 inches, with a 2-inch topaz crystal associated (L. Spaulding, Jr. collection). Three others that are very close in quality are in the B. Harris, J. Scripps and D. Wilber collections.

Axinite. Usually only poor single crystals are produced at this locality. One specimen that has achieved greatness has been preserved: a 3 x 4-inch cluster of 1-inch translucent axinite crystals with associated cleavelandite (B. Harris Collection).

Hambergite. Hambergite has been produced in small pockets associated with the topaz-tourmaline pockets at the Little Three mine. Numerous fine single crystals are known for this rare species. One of the largest and finest is a 2¼ x 1½ -inch single crystal in the San Diego County Museum of Natural History collection.

Hercules Mine

Spessartine. Adjacent to the Little Three mine, the Hercules has produced large quantities of fine gem spessartine. The finest specimen, which is probably the finest spessartine specimen known from *any* locality, is a small matrix piece that consists of several sharp orange crystals up to 1 inch associated with rosettes of cleavelandite and a single sharp, black 1¼-inch schorl crystal (Smithsonian collection). Other notable spessartine garnets are in the D. Wilber collection (Fig. 7) and the J. Scripps collection.

***Figure 11.* TOPAZ, pale blue, 1 x 1½ inches, with cleavelandite albite, from the Little Three mine, Ramona District, California. Collection of B. Larson; photo by Harold and Erica Van Pelt, photographers, Los Angeles.**

Microcline. One superb, sharp, white, 4 x 2 x 2-inch single crystal with ¼-inch gem spessartine garnets attached near the base is certainly one of the finest (J. Scripps collection.)

JACUMBA DISTRICT

Beebe Hole mine

Spodumene. Recently discovered, this locality has produced numerous spodumene crystals of yellow, blue and purple color. The finest is a 6 x 4-inch single crystal of kunzite (L. Beebe collection, Spring Valley, California).

Rare Minerals Report

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I would like to remind readers, as I stated in the last column, that there is some delay between the writing of this and the printing of the *Mineralogical Record*. For example, this installment had to be submitted in early August in order to appear in the November-December issue. I am advising some of the dealers of this so that they can try to retain some of the mentioned species in stock.

I would like to offer a service to collectors, curators and researchers who read the *Record*, and that is to answer letters regarding specific rare species requests. I will make a serious effort to locate a species for a collector or for research purposes (please indicate which) but I must stipulate that I cannot help collectors who send a list of hundreds of species (although it always interests me to see such lists and add them to my file). But if the request can be kept to three or four species I will do my best to help locate them.

I appreciate receiving dealers, and collectors' lists and letters giving news of rare species they have available, and will make use of these in my column as space permits. This particular installment was derived entirely from dealers' lists and letters. I highly recommend that collectors and curators keep all dealers' lists for a number of reasons. They contain valuable locality information (as, for example, the Japanese localities given in Abe Rosenzweig's list quoted herein). They also contain valuable information on quality, sizes and prices.

Sometimes dealers' lists contain a type of information that should probably *not* have been printed: mineral names not yet formally published, even though accepted by the IMA (the International Mineralogical Association). It is currently considered improper to use a species name before it has been formally published, even though we would all like to know about it, and dealers would like to be able to sell it (which is difficult to do when no name can be given). This presents a problem to collectors, curators and dealers alike, and will be discussed further in a future editorial.

And now to the rare minerals.

David Garske has advertised the following: **aguilarite** (San Carlos mine, Guanajuato, Mexico), **antlerite** in superb crystals (Chuquicamata, Chile), **ferroaxinite** (Dome mine, South Porcupine, Ontario), **gerhardtite** (Likasi mine, Zaire), **lueshite** (Lueshe, Zaire), **parakeldyshite** (Lagendalen, Larvik, Vestfold, Norway), **paraspurrite** (Darwin, California), **robertsite, jahnsite, segelerite** and **whitlockite** (Tip Top mine, Custer County, South Dakota), **sampleite** (Chuquicamata, Chile), **tellurantimony** in altaite (870 level, Mattagami Lake mine, Mattagami, Quebec), **wodginite** with epitaxial cassiterite in superb crystals (Galilea, Minas Gerais, Brazil) (an article describing these specimens is coming in the *Record*. Ed.), **brandtite** (Harstig, Wermland, Sweden), **cafarsite** (Mt. Cervandon, Alp Devero, Novara Province, Italy), **calumetite** (Calumet, Michigan), **schairerite** (Searles Lake, California), **neyite** (Alice Arm, British Columbia), **talmessite** (= arsenate belovite) (Criss Creek, near Savona, British Columbia), **goedkinite**, a new species (Palermo mine, North Groton, New Hampshire), **hinsdalite** (Sylvester mine, Zeehan, Tasmania) (See Mineralogical Notes in the last issue. Ed.), **macfallite** (near Copper Harbor, Michigan), **rancieite** (Mont Mirat, Lozere, France), and superb crystals of **piemontite** (Ultevis, Sweden). This piemontite looks like stubby tourmaline crystals at first glance; it is dark red to black, occurs in brilliant crystals to 6 mm and broken sections to 1 cm, in association with powellite.

On occasion, living in Rochester, I drop in at ***Ward's Natural Science Establishment*** and, on occasion, they have some rare species available. As of this writing they have **svanbergite** (Horrsjoberget, Sweden), **hjelmite**, which was recently redefined in the *American Mineralogist* (Stripasen, Sweden), **tellurobismuthite** (Boliden, Sweden), the unnamed **aluminum analog of jahnsite** (Taquaral, Minas Gerais, Brazil), and **pinakiolite, litharge, tilasite, melanotekite, kentrolite, berzeliite** and the very rare **blixite** (Långban, Sweden).

Abe Rosenzweig recently put out a list containing some very rare and interesting Japanese minerals, including the following: **fukuchilite** (Hanaoka mine, Ohdate-shi, Akita-ken) (Note: "shi" = city, "gun" = island, "machi" = town, "ken" = prefecture. Ed.), **ishikawaite** (Ishikawa-machi, Ishikawa-gun, Fukushima-ken), **kobeite** (Ushio mine, Omyia-cho, Kyoto-ken), **osarizawaite** (Osarizawa mine, Akita-ken), **nakauriite**, a new species (Nakauri-shi, Aichi-ken), **bicchulite** (Fuga, Kawakami-gun, Okayama-ken), **sugilite** (Iwagi-gun, Ehime-ken), **yoshimuraite** (Tanohate mine, Iwate-ken), **yugawaralite** (Seikoshi mine, Toimachi, Shizuoka-ken), **stannoidite** (Akenobe mine, Yabu-gen, Hyogo-ken), and the unnamed **joaquinite-like mineral** (Hashidate, Ohmi-machi, Niigata-ken) which has also been found at the Benitoite Gem mine. Abe's address is Department of Geology, University of South Florida, Tampa, Florida 33620.

Sharon Cisneros of ***Mineralogical Research Co.*** recently listed the following: **keldyshite** and **parakeldyshite**, a new species (Lagendalen, So. Norway), **stringhamite** (Christmas mine, Gila County, Arizona), **sugilite** (Iwaki-jima, Ehime, Japan), **tugtupite** (Kvanefjeldet, Ilimaussaq, Greenland), **valleriite** (Pima mine, near Tucson, Arizona), and **westerveldite** (Ilimaussaq, Greenland).

John Metteer of the ***Mineral Mailbox*** (he has now joined the *Record* as an advertiser. Ed.) recently listed **cafarsite** (Cervandon, Italy), **eulytite** in nice crystals (Johanngeorgenstadt, East Germany), **gordonite** (Fairfield, Utah), **laurite** (Cala, Colombia), **leadhillite** (from the Beer Cellar mine, Grandby, Missouri, an old classic locality), **naujakasite** (Naujakasik, Tunugdliarfik Fjord, Greenland), **sampleite** (Chiquicamata, Chile), **alamosite, leiteite, schultenite, tsumebite** and **arsentsumebite** (Tsumeb, Southwest Africa), choice **valentinite** crystals to 3/8 inch (Oruro, Bolivia), and superb crystals of **kleinite** to 3 mm, the world's best (McDermitt mine, Humboldt County, Nevada; originally listed as being from the Cordero mine, the locality designation has recently been corrected by the dealer).

Minerals Unlimited recently offered **agardite** (Bou Skour, Morocco), **agrellite** (Kipawa Complex, Villedieu Township, Quebec), **bandylite** (Chuquicamata, Chile), **bellingerite** (Chuquicamata, Chile), **briartite** (Prince Leopold mine, Kipushi, Katanga, Zaire), **carrboydite** (Carr Boyd nickel mine, W. Australia), **foggite** (Milgun Station, W. Australia), **melonite** (Cresson mine, Cripple Creek, Colorado), **nambulite** (Gozaisho mine, Iwaki-shi, Fukushima-ken, Japan), and **berryite** (Mike mine, San Juan County, Colorado). A long list of about 600 species currently in stock is available but since no localities or other details were given, no excerpts are presented here.

Gunar Penikis carries quite a few rare species from the Yukon phosphate locality including **kulanite, penikisite, baričite, maricite, arrojadite** (crystals!), **gorceixite** (crystals!), **kryzhanovskite** and the **aluminum analog of jahnsite**. According to Joe Mandarino of the Royal Ontario Museum (pers. comm.), penikisite is much rarer than has been thought; most is actually kulanite which is compositionally zoned and which contains only a small percentage of penikisite.

continued from page 496

of these minerals. The broken nature of the rock would allow relatively easy access for air to enter the system and cause concentration of solutions and crystallization of the minerals by evaporation.

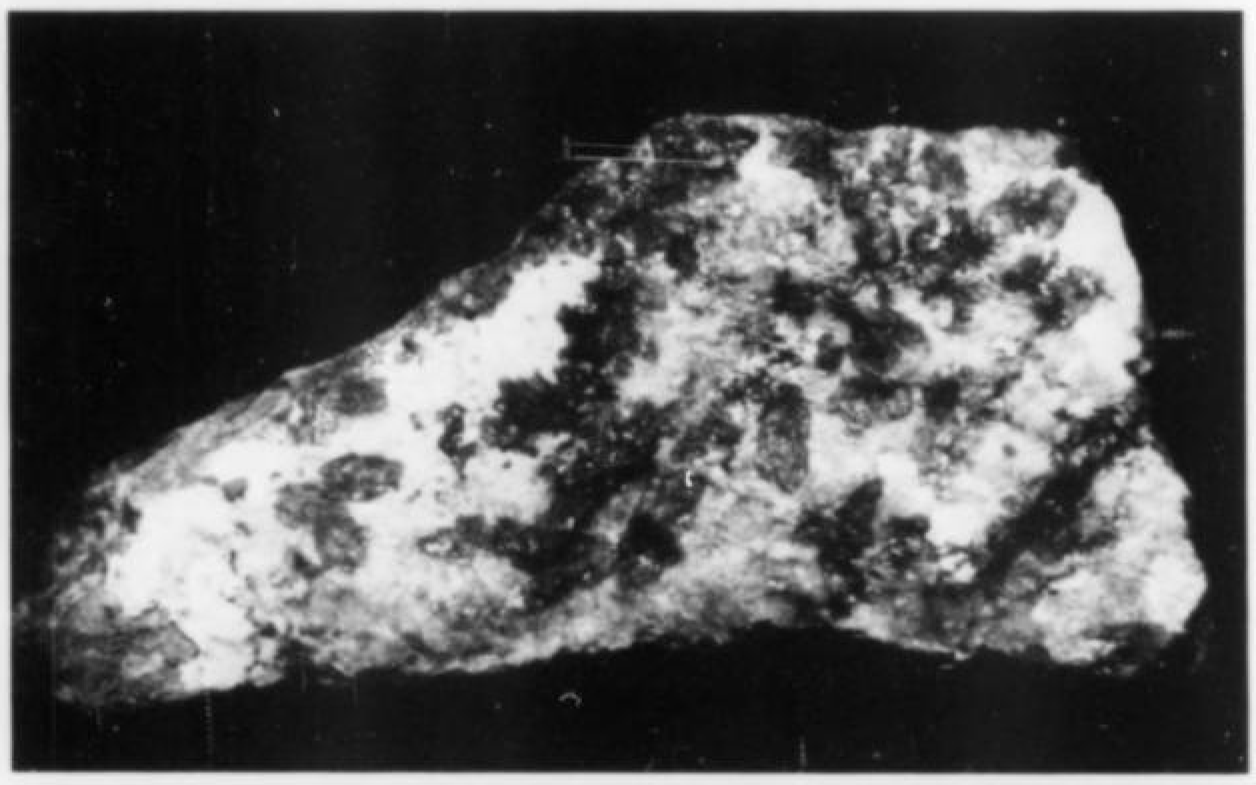
COLLECTING

The mine is accessable to two-wheel-drive vehicles. Take the Zzyzx Road turnoff about 9.5 km southwest of Baker, California, on Interstate 15. Follow the road north over the overpass and continue in a northwesterly direction up the alluvial fan for approximately 6.5 km. The Blue Bell mine and other workings can be seen on the higher hill west of the road. The mine is posted, and the owners are usually present on weekends. The mine, at an elevation a little over 860 m, has been heavily prospected by mineral collectors. The dump has apparently been turned over more than once. Nice specimens are still obtainable from the stope. The rear of the stope and the right side will yield dioptase and wulfenite. The floor is virtually untouched and has yielded some nice linarite on anglesite. The roof near the front of the stope will yield leadhillite and caledonite from the ore zone. A portable and fairly long aluminum ladder is needed. The dump will still yield small specimens of all the species. Chrysocolla-rich ore will yield chlorargyrite, which has been overlooked by most collectors.

ACKNOWLEDGEMENTS

The author wishes to thank Ian Lange, William B. Sanborn and H. Earl Pemberton who critically reviewed the manuscript and provided helpful suggestions.

***Figure 5.* Turquoise-blue caledonite and colorless leadhillite on matrix 4 x 8.5 cm, from the Blue Bell mine.**



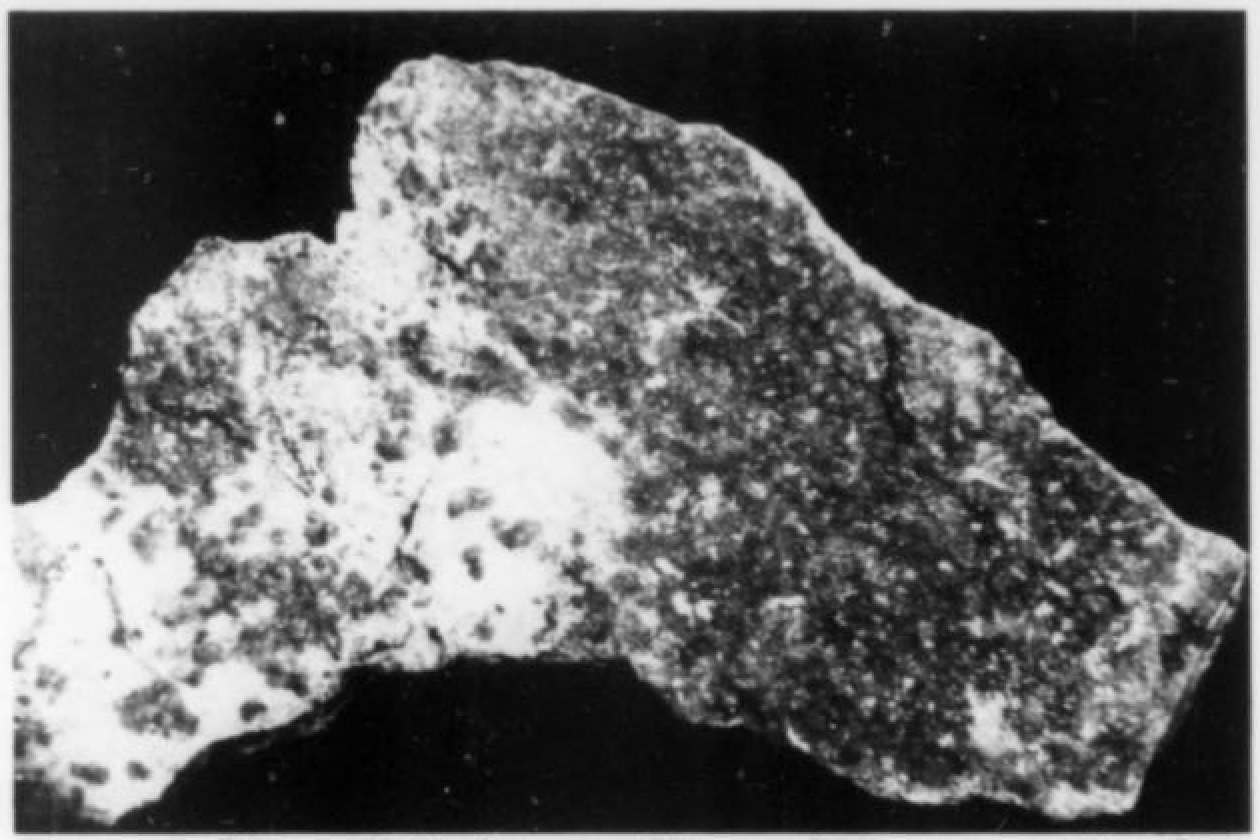


***Figure 6.* Blue caledonite on white anglesite on matrix, about 3.5 x 8.5 cm, from the Blue Bell mine.**

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Mineralogical Notes

ANDRADITE FROM THE JUNNILA MINE, CALIFORNIA

A new occurrence of specimen-quality andradite, **$Ca_3Fe_2(SiO_4)_3$**, is located at the Junnila mines, near the New Idria mine, San Benito County, California. The four specimens examined herein were obtained from Crystal Cavern Minerals of 1800 Arnold Palmer Drive, El Paso, Texas, 79935.

The andradite occurs as small, light green, brown and dark brown (almost black) euhedra varying in size from 1-10 mm, with most of the crystals being about 3-4 mm. The crystals are implanted on a serpentinite rock and present very esthetic specimens. There are samples totally covered on one surface with interlocking crystals, as well as samples with isolated euhedra on matrix. The morphology of the andradite is simple: most of the crystals are dodecahedral in habit, having the dodecahedron {110} modified by small faces of the trapezohedron {112}. When cleaned, the specimens are very lustrous.

Figure 1. **Andradite (medium yellow-green), San Benito County, California. Crystal size is 5 mm.**

TABLE 1.
Microprobe analyses of Junnila mine andradite

Color	green	light brown	brown	dark brown	
NMNH#	136883	136881	136880	136882	THEORETICAL ANDRADITE
SiO_2	35.73	36.27	35.96	35.93	35.48
TiO_2	**0.04**	**0.07**	**0.14**	**2.36**	
Al_2O_3	0.23	0.32	1.80	0.08	
Cr_2O_3	0.07	0.08	0.10	0.08	
Fe_2O_3*	30.82	30.19	28.45	28.43	31.42
MgO	0.11	0.25	0.25	0.56	
CaO	33.32	33.63	33.77	34.15	33.10
MnO	0.07	0.07	0.07	0.08	
Total	100.39	100.88	100.54	101.67	100.00

* total iron calculated as Fe_2O_3.

Accuracy of data - ±2% relative.

Four specimens in the Smithsonian collection were analysed with an electron microprobe using an operating voltage of 15 kV and a beam current of 0.15 μA. Standards used were almandine and hornblende and the data were corrected for fluorescence, backscatter, background and absorption with a computer program. The resultant analyses are given in Table 1.

The analytical data verify that the Junnila mine crystals are indeed andradite. The composition of the crystals is quite close to that of end-member andradite (Table 1) and there is little substitution of other cations except aluminum and titanium. It is interesting to note that the color of this andradite darkens with increasing titanium.

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KINOITE FROM MICHIGAN – A NEW OCCURRENCE

INTRODUCTION

In 1974, kinoite, **$Ca_2Cu_2Si_3O_{10}\cdot 2H_2O$**, was found in the Kearsarge Lode near Calumet in Michigan's "Copper Country." It was first observed as minute azure-blue crystals occurring as inclusions in quartz and calcite. Several years were spent utilizing X-ray diffraction, optical, and electron microprobe techniques before identification was possible. This paper presents the results of these studies.

PREVIOUS WORK

Kinoite was first described by Anthony and Laughon (1970) as occurring in contact metamorphosed limestones and dolomites of Paleozoic age in the Santa Rita Mountains, Pima County, Arizona. The Arizona material occurs as veinlets filling cracks and as single crystals which, with copper, are embedded or partially embedded in apophyllite. Other associated minerals are djurleite, bornite, and chalcopyrite.

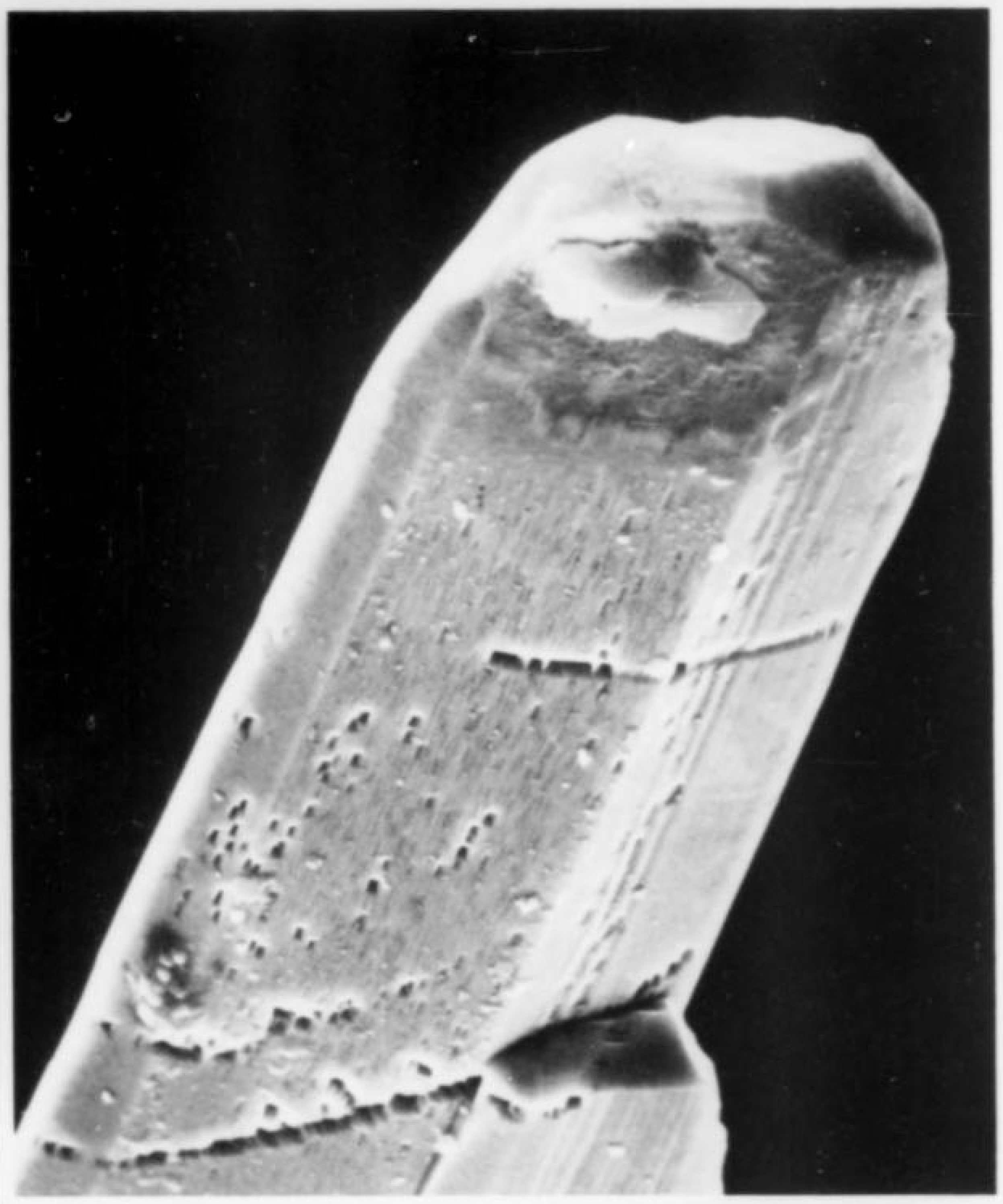

Figure 1. **Electron micrograph of a single kinoite crystal from the Kearsarge Lode near Calumet, Michigan. Note the pseudo-orthorhombic habit and the etch pits caused by acid leaching. Crystal width is 0.075 mm.**

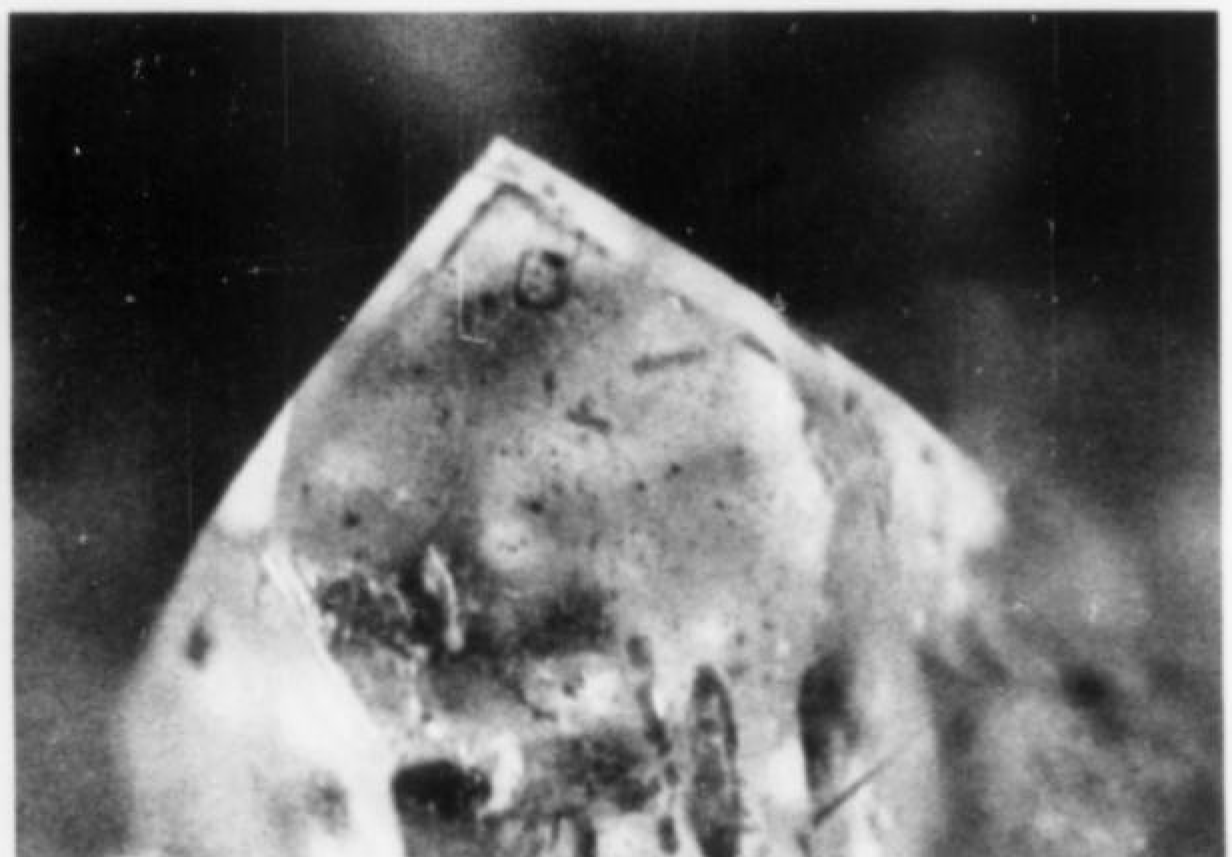

Figure 2. **A quartz crystal with kinoite crystals partially coating a "phantom" just beneath the surface. The quartz crystal (from the Kearsarge Lode) is 1 mm in width.**

PHYSICAL AND OPTICAL PROPERTIES

Crystals from the Michigan locality are azure-blue, tabular, monoclinic, and pseudo-orthorhombic. Unit cell dimensions were obtained following the Weissenberg X-ray diffraction method of Buerger and optical properties were determined using a spindle stage. The results are given in Table 1. These values correspond remarkably well to those given by Anthony and Laughon for the Arizona material.

TABLE 1.

Physical and Optical Properties of Michigan Kinoite

Optical:	Unit Cell Dimensions:
α = **1.640** ± .002	a = **7.01** ± .01Å
β = **1.663** ± .002	b = **12.92** ± .01Å
γ = **1.680** ± .002	c = **5.67** ± .01Å
opt. sign (-)	V = **512.71**Å
2V = **80°**	β = **96°00′**
space group = **$P2_1/m$**	

PARAGENESIS

Michigan kinoite occurs embedded in calcite and quartz amygdaloid fillings in the Keweenawan basalts of the Kearsarge Lode. It is important to note that the following sequence is only rarely observed in its entirety on a single specimen; most specimens show interruption or termination of the sequence at one or more stages. However the general sequence of formation of the minerals associated with Michigan kinoite appears to be as follows:

1. Basalt solidified, containing vesicles (gas bubbles).
2. Epidote formed in some but not all vesicles.
3. Quartz began forming on vesicle walls or on epidote.
4. When the quartz crystals had reached 1-10 mm in size, kinoite crystals began forming with their largest faces parallel to quartz faces. Simultaneously, native copper and native silver began crystallizing. Also at the time, calcite crystals began nucleating on kinoite crystals that were floating free in the solution. These calcite crystals grew to include crystals of kinoite, copper and/or silver.
5. While quartz and calcite were still crystallizing, kinoite not protected by inclusion in other crystals began to dissolve. Evidence of this is seen in skeletal crystals preserved in quartz.
6. Quartz ceased to crystallize but calcite continued to form, in some cases completely filling the vesicles to form solid amygdules.
7. Remaining spaces left after the end of calcite crystallization were filled with pumpellyite, chlorite and saponite.

The end result is quartz crystals with kinoite forming "phantoms" just under their surface, and calcite crystals with kinoite in their centers. These crystals are associated with epidote, native copper, native silver, pumpellyite, chlorite, and/or saponite crystals with an occasional chalcocite crystal following later.

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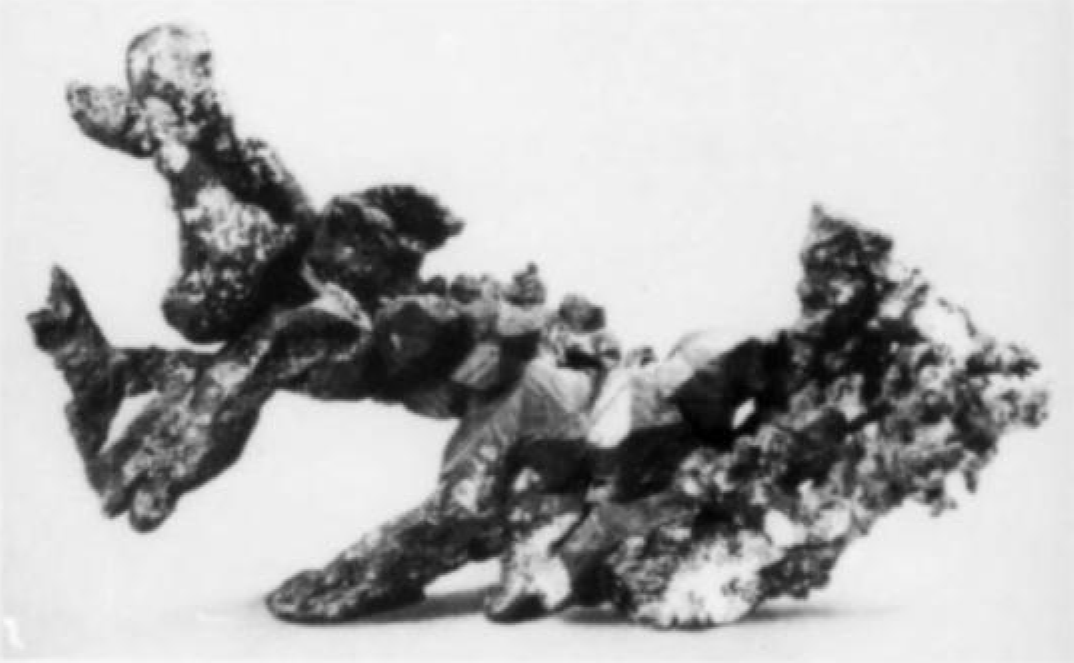

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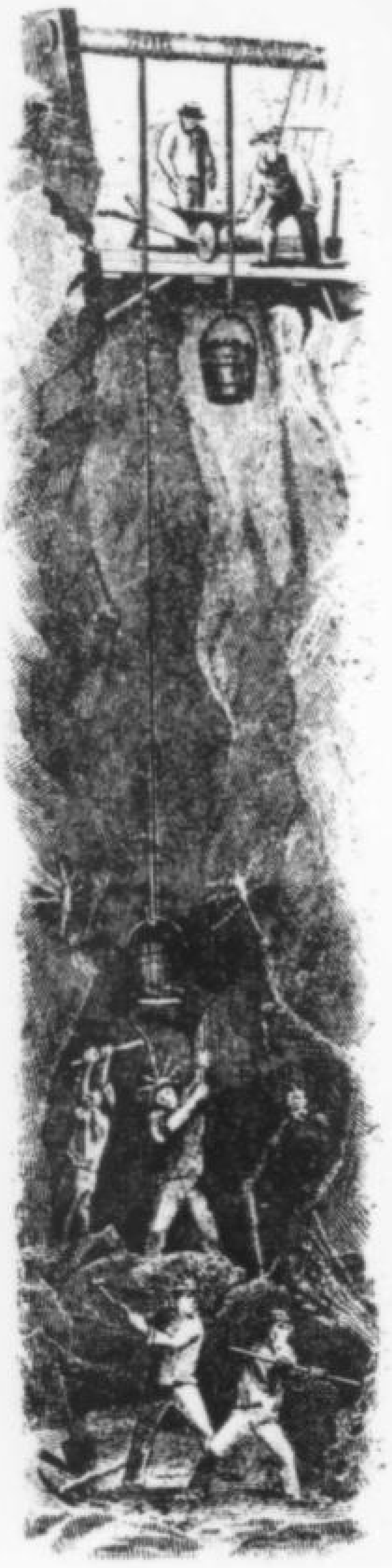

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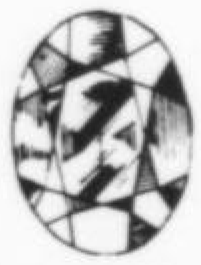

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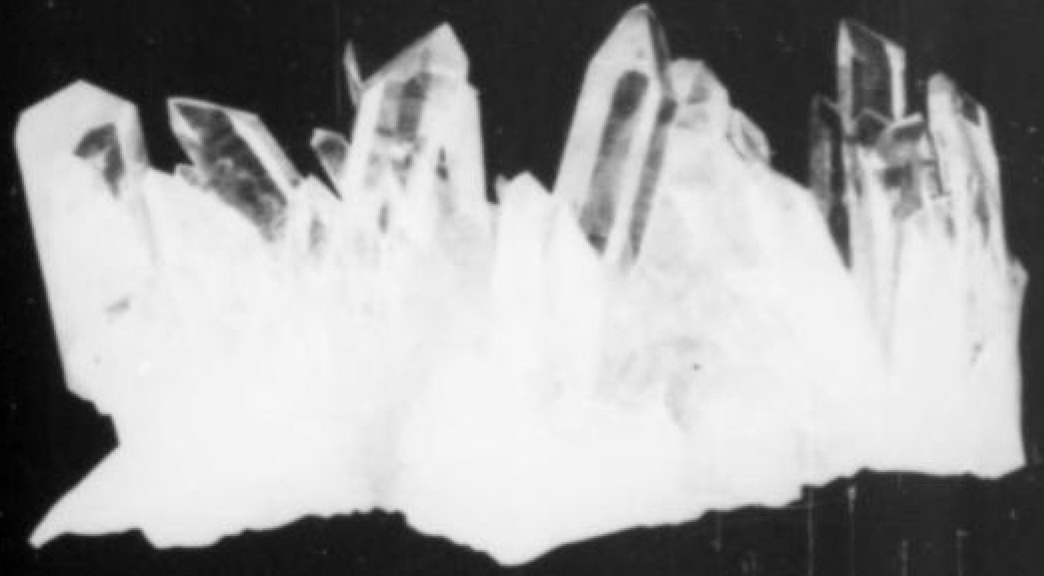

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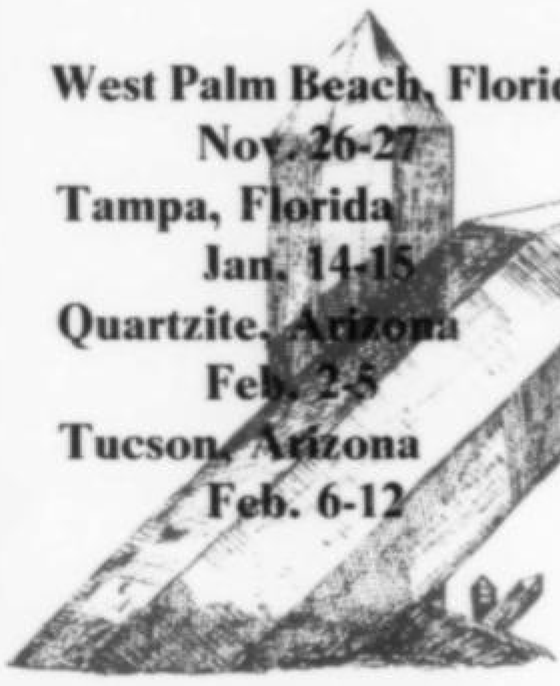

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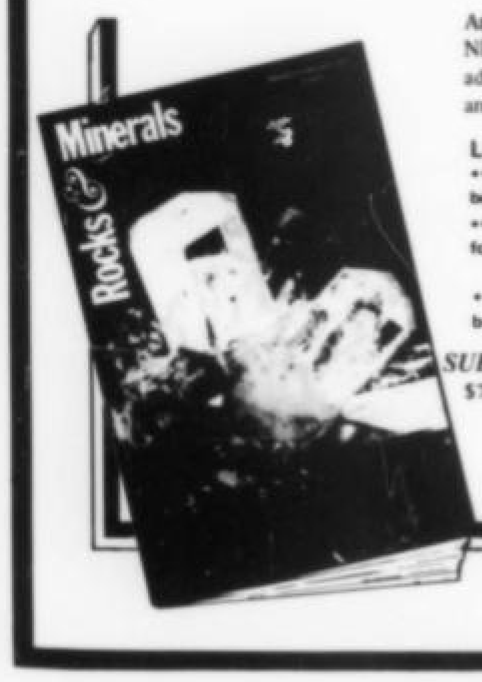

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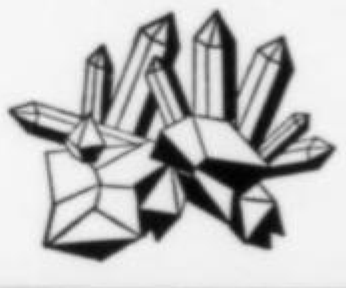

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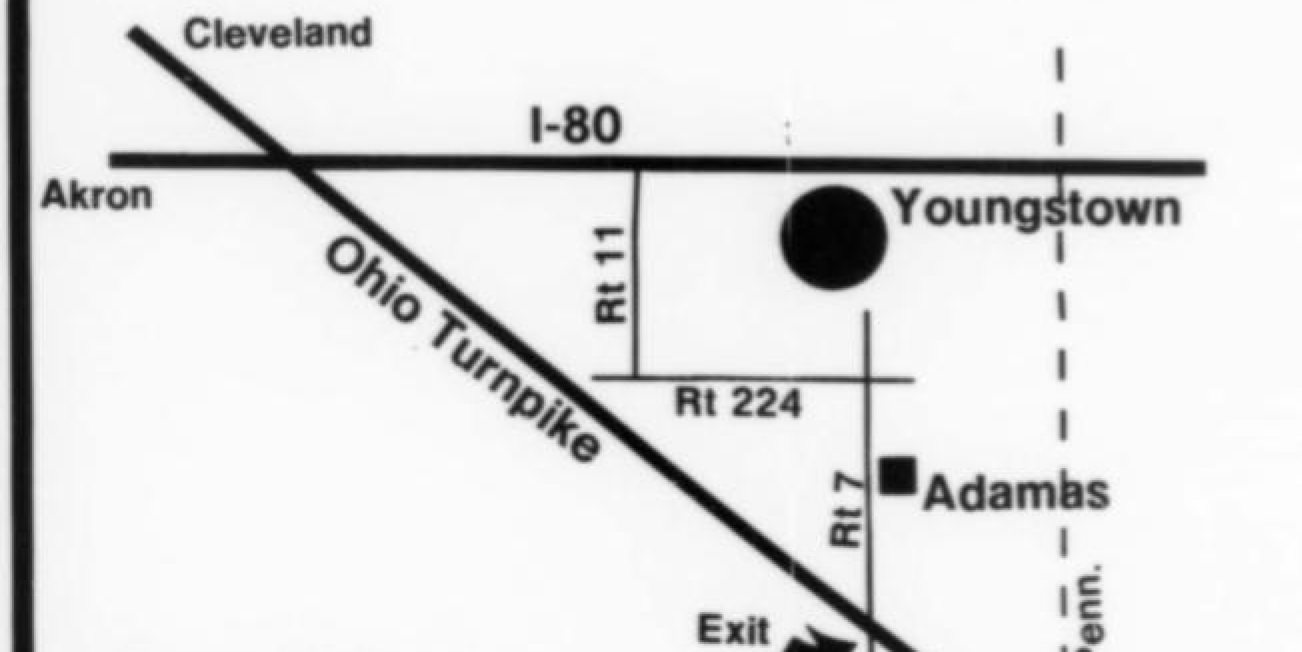

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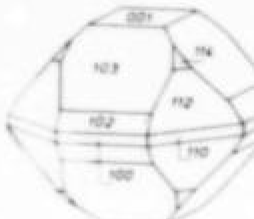
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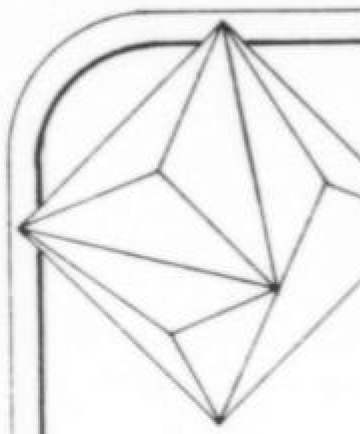

INDEX TO VOLUME EIGHT (1977)

Note #1: The special book-issue on Tsumeb (title: **TSUMEB!**), vol. 8, no. 3, was numbered independently starting with page 1; page references to the Tsumeb issue are preceeded by **T** (e.g. **T27** refers to page 27 of the Tsumeb issue, rather than to page 27 of vol. 8, no. 1). **Note #2:** All reference numbers in this index refer to page numbers **except** references in the authors' list, which refer instead to article numbers given at the left of the feature article and department entries.

FEATURE ARTICLES (FA)

DEPARTMENTS (D)

AUTHORS

(References are to entries on the above Feature Article (FA) and Department (D) listings, and not to page numbers.)

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6. Names and addresses of publisher, editor, and managing editor: Publisher, John S. White, Jr., 12304 Welling Lane, Bowie, Md. 20715: editor, Wendell E. Wilson, 1836 Tree View Court, Crofton, Md., 21114; managing editor, none.
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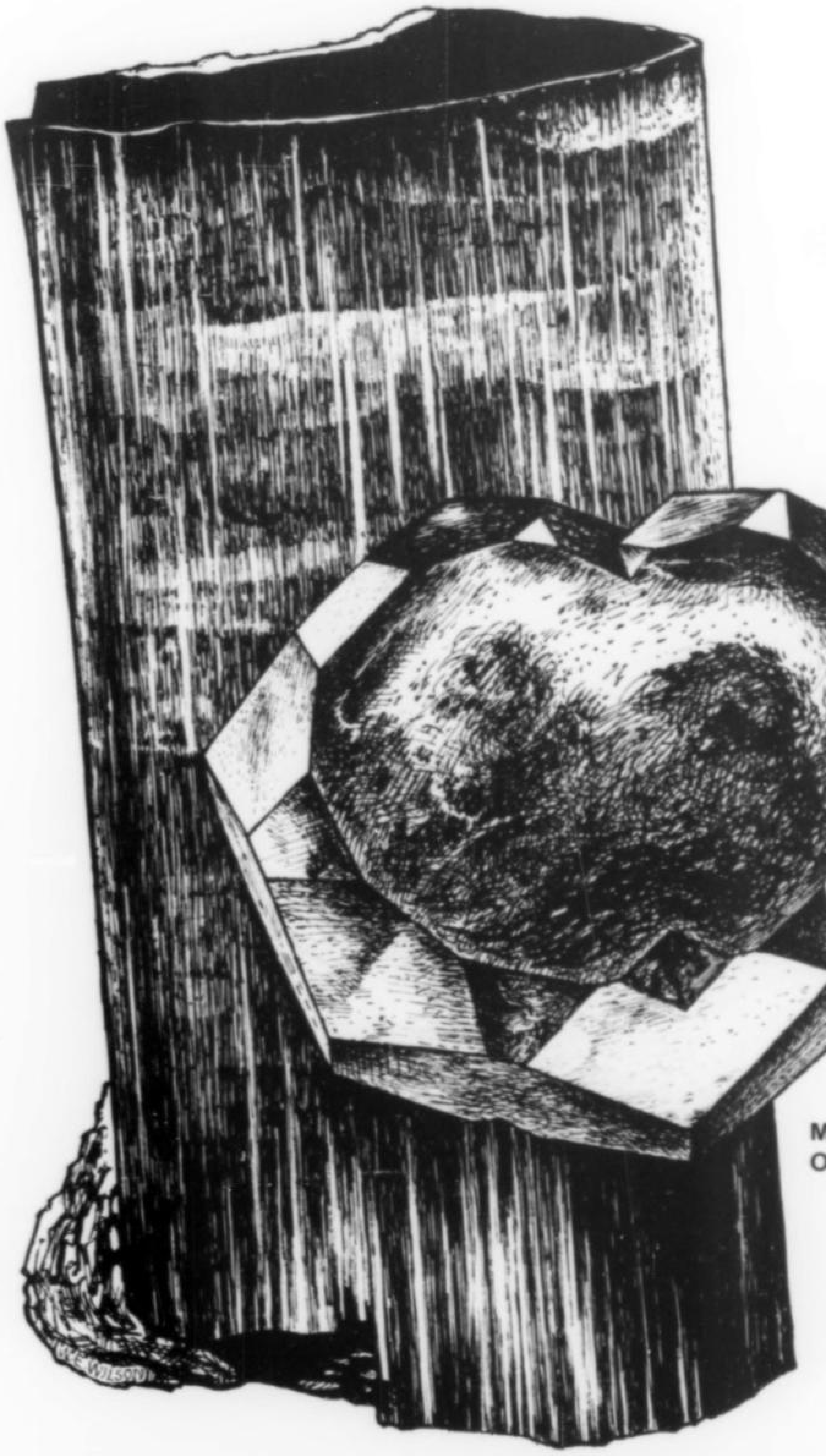

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