the Mineralogical Record

Volume 2 / Number 3
MAY / JUNE, 1971

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editorial matter

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feature articles

departments

Rhodochrosite, from the Grube Louise, Horhausen, Nassau, Germany. The specimen, part of the Smithsonian collection, is about 2 cm across. Minute fractures within the crystals scatter light, thus accounting for their apparent "glow." Illumination is provided by a high-intensity microscope light, positioned very close to the specimen. Photo is by Joel E. Arem, and won the Mineralogical Record photo contest in Tucson, February 1971.

To the Editor

Dear Sir:

In sympathy with the plight of all publishers when time for renewal of subscriptions arrives, and realizing that constant subscription growth is necessary to establish a name for a new publication, with lamentable procrastination I send you my check and a suggestion.

Could not those of us deriving much pleasure from the *Mineralogical Record* visit our local public libraries, museum libraries, and those of our local schools and colleges, armed with our issue—and urge them to subscribe? There is not a library in the country which does not circulate to many science teachers, mineral collectors and enthusiasts, but many of their subscription budgets are small. Unquestionably, personal enthusiasms can produce more wonders than countless expensive pleas from a neophyte publisher.

Many of the school libraries reevaluate their present magazine needs, and reshuffle their budgets during the summer months. If each of us could convince one or two of our local educational establishments to subscribe to the *Mineralogical Record,* would it not offer a substantial transfusion to the lifeline of your great young publication?

You can count on me!

Janet Louise Hallowell
Pottstown, Pennsylvania

Dear Sir:

With regard to the article in *Mineralogical Record* Jan/Feb 1971 in the "What's New in Minerals" column, reference is made to vivianite from Mexico. In 1965 when we were in Santa Eulalia, Chihuahua, we were offered a small selection of vivianite cyrstals which rivaled the quality and size of the Bolivian material. Since we had already spent all our money, after going to the bank the next day and cashing some travelers checks, we returned to find the specimens sold early in the morning to someone else. But they were offered by the miners who live in the town, so we have not the slightest doubt that the specimens originated from the area—where else would these people have come into possession of such material??? The best specimens were composed of two crystals of at least 2-1/2 inches long, growing side by side and of the characteristic blue/purple/greenish hue, and fully transparent, on a minimum of matrix. Excellent display type, and they were asking for $40 U.S. which is a *sizable* amount of money for one individual specimen in this area.

As for the scorodite and ludlamite, we have never heard of these specimen types coming from Mexico either.

Sharon Cisneros
San Jose, California

Dear Sir:

I desire to take this opportunity to express my appreciation for the very fair and objective review of my book, *An Abbreviated Manual of Franklin Minerals.* With economy of word, but with a very deep understanding of what I tried to do in my first attempt in the field of mineralogy, you analyzed the effort perfectly.

This is typical of your entire publication. Clarity, accuracy, and above all the conscious desire to make available to the public an outstanding journal.

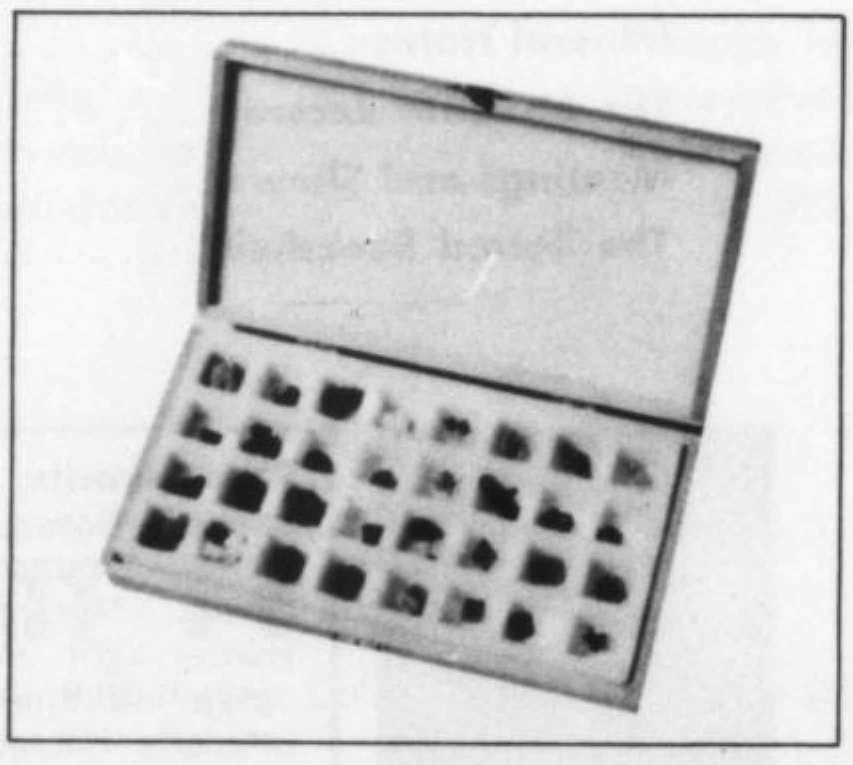
Ervan F. Kushner
B.S., LL.B (J.D.)
Paterson, New Jersey

Dear Sir:

I have noticed that out of about thirty fine articles on minerals in the last five issues, fully half contained not a single photo of a specimen. Much as I appreciate seeing a map of an area or a photo of local scenery, I think a photo of the mineral itself should be the first prerequisite. Moreover, I would personally be glad to pay one to four dollars more per year if you would have a center section (with a foldout?!) of 4 or 8 pages of COLOR photos of fine specimens from museums and/or private collections. After all, where lies most of the pleasure of collecting if not in simply looking at beautiful specimens? Your covers are marvelous, especially the last two. Perhaps your other readers would like to comment on the addition of color photos inside the *Mineralogical Record.*

Wendell Wilson
Tempe, Arizona

In regard to your first suggestion, I think you will notice continued improvement as we press our authors for more specimen photographs. As for color inside, we simply cannot afford to offer it at this time. We are eager to use color plates in the Record and will do so when the circulation is sufficient to permit it. Ed.



EDITORIAL PAGE

Educational Exhibits

It has always seemed strange that sponsors of mineral shows in this country would invest heavily in trying to attract the general public to their shows, then leave completely to chance the important business of instilling in these people a keen interest in learning more about minerals.

A visitor, entering a mineral show for the first time, finds a maze of display cases full of minerals and jewelry and counters loaded with minerals, fossils, jewelry, and literature for sale. He finds specimens glistening with shiny surfaces, some of which are natural crystal faces, some cut and polished (*lapidated* as Bob Dowell would say), but no prominently-displayed explanation can he find of how these faces come to exist. He finds a thousand-dollar specimen surrounded by two-dollar specimens but no explanation of what makes one so much more costly than the others. He may search all day and discover not one word about where the "stars" of the show, the minerals, came from or how they were recovered.

How many show sponsors prepare and hand out literature detailing the location of a nearby collecting site so that a first-time visitor may follow up the show by trying his luck at finding a specimen on his own? How can mineral clubs pass up such an opportunity to attract new members? How often does one see distributed at shows literature about the clubs in the region represented by the show? When most of the school-age population of a city, or community, is paraded through a mineral show, the attendance at subsequent club meetings should show a substantial increase. To my knowledge, this kind of response is rare. Why do mineral shows fail to stimulate and enthuse visitors to such a degree that attendance at club meetings following the shows does not soar? The answer, unfortunately, is that the shows are not attempting to educate.

Thus it is gratifying to find the Friends of Mineralogy grappling with the concept of educational exhibits and actively promoting the production of them. FM is entering a green field, virgin territory, a new frontier. Few museums have attempted to apply modern educational theory to topical exhibits in mineralogy. Nearly all existing exhibits are, more or less, variations on the classical treatment of morphological crystallography, physical properties and, perhaps, something about crystal structure. It is sad indeed that the *professional exhibitors* are not doing the pioneering. Whatever their reason, whether it is a failure to recognize the need for a new direction in exhibiting or an unwillingness to tackle the problem, they have left it wide open for an activist group like FM.

Because promoting educational exhibits of minerals is such a pioneering effort, one is not surprised to find that the going is not easy. Guidelines, until tested, seem much simpler to formulate than they really are. Missteps must be taken before the path becomes clearly defined. Therefore potential critics should not be anxious to condemn and point up shortcomings, but must come forward with helpful suggestions. It will take years before collectors come to appreciate all that is required to make an exhibit original and truly educational. After all, it took a long time for competitive exhibitors to discover the techniques that help to make a display attractive, and new techniques are being introduced continually. This is true in spite of the fact that all they had to do was copy the technique of the best exhibitor.

Let us hope that complex and detailed "rules" do not evolve. Better to allow the exhibitor great freedom and, if his effort succeeds, a set of "uniform rules" will not be required in order to arrive at a point total that proves the exhibit was a success. The exhibit speaks for itself! Better to follow good examples than to be led along by rules. ■

John S. White, Jr.

Q/A column

Q. Byssolite—what is it? Dana describes it as a stiff, fibrous variety of asbestos, which, in turn, is a soft fibrous variety of amphibole. Asbestos, too, is designated as a soft fibrous variety of serpentine—chrysotile. I've seen the green material included in calcite from French Creek, Pa and the so-called byssolite from Cornog, Pa., which, in this case, seems to be thin, cottonlike material, a step down in size from actinolite.

My own feeling is that byssolite is not a mineral, but is a form, a condition, and should not be entered on labels as a mineral. Please clarify.

Walter Steinau, Clinton, Massachusetts

A. In *Dana's System* byssolite is described as "related to," not a variety of, asbestos. Until you raised the question there was never any doubt in my mind that byssolite was anything but a stiff, fibrous form of amphibole. While it is definitely not a meaningful mineral name, it is a useful term for describing a rather common habit of some amphiboles, chiefly actinolite-tremolite and hornblende. Thus the term should be used only as a modifier, never as a mineral name. Unfortunately, as is usually the case, the leading reference works are not unanimous in this and at least one describes byssolite (also amianthus) as synonomous with asbestos. From popular usage, in the U.S. at least, I take issue with this. I have never seen byssolite used for any but stiff, fibrous amphibole, seemingly formed hydrothermally in open fissures or pockets and nearly always associated with epidote, albite and quartz. Asbestos is soft, flexible, forms in a variety of environments, and may be either an amphibole or a serpentine mineral.

Q. Can a person legally tie up a collecting area under a mining claim? How does the term "economical find" affect this, when only specimens are produced?"

R. E. Pedersen, Monrovia, California

A. (The answer to Mr. Pedersen's question was provided by Richard W. Thomssen, of Tucson, Arizona, a registered exploration geologist and a mineral collector).

1. Is a mining claim on a collecting locality valid?
   Answer is *yes* with the following provisos—
   (a) Ownership of the mineral rights is vested in the U.S. Government.
   (b) The mineral(s) of interest are not specifically excluded by law from mining claim location. These include: petrified wood regardless of replacing material, coal, oil, gas, oil shale, sodium, phosphate, and potassium (these mineral substances must be leased under the Leasing Act of 1920).
   (c) The mineral(s) of interest are of sufficient interest or value that a reasonably prudent man will expend money on their development.
   (d) All applicable laws relating to monumenting of the claim boundaries, location work, and filing of notices are exactly followed.
2. Do recent rulings on a find having to be economic have any bearing?
   Answer is *no* with the following qualification—

The principle noted in paragraph (c) above can be met. The economic question has been raised by the Forest Service concerning claims staked within National Forests. As far as I am aware this test, if actually applied, has no legal basis, but is in fact a bureaucratic invention.

continued in next column

As you can see, in controversial areas the actual economic (or scientific?) value of the mineral(s) of interest will determine the extent and degree of response on behalf of the claim locator to questions of claim validity which might be raised by Forest Service or Bureau of Land Management personnel.

Yedlin on Micromounting

The old order changeth, etc. A great mineral dealer, who supplied the needs of collectors throughout the world (A visit to whom was an obligation for anyone within several hundreds of miles of Easthampton, Mass.) has, on May 1, 1971, disposed of his material, lists and equipment. The Schortmanns have retired, after some 35 years in the mineral specimen business. The purchasers, the Bentleys, of Windsor, Conn., who with their sons have acquired the assets, are presently constructing showrooms, and will probably be open for business when this column appears in print. The Bentleys are themselves collectors, know mineral specimens, localities and equipment, and plan to supply all needs of the serious hobbyist. You'll hear from them.

Things we quickly recall about the Schortmanns: (The late Ray Schortmann was one of the founders.) The superb mineral shows in New York City, held prior to and during World War II, and the crowds that gathered, awaiting the opening hour . . . Our being the only collector ever to have viewed the displayed minerals prior to official opening (We were in uniform and "moving out" the next day . . . and were permitted entry only if we did NOT purchase anything) . . . Ray's setting up the fine mineralogical museum at Amherst College . . . The fine collections acquired by them for disposal to collectors and museums—Burrage, with its fine specimens and plethora of gold . . . The Brooklyn, N.Y. Children's Museum collection when it was broken up . . . The superb European stocks, some of noted historical people, most of the material going to National Museum of Natural History, American Museum, Harvard, Royal Ontario Museum, Princeton, Cranbrook, and others before being released to private collectors . . . The acquisition of the William Ball Franklin collection, with its superb 1 inch zincite crystal which went to Cranbrook via A.N. Goddard . . . The great sepcimens from Fairfield, Utah; Mammoth mine, Ariz.; Pala, Cal. tourmalines; magnificent epidotes from Alaska; and Central City, Colorado pyrites (with diploids!) supplied by Ed Over and Arthur Montgomery . . . the events seem endless . . . And finally, the evenings spent going through the Fairfield and Mammoth mine stocks, and coming up with wardite, gordonite, englishite, lewistonite, kolbeckite, millisite, montgomeryite and overite from the former, and finding new cranberry-colored, prismatic crystals, on diaboleite, from the latter.

A few of our remembrances. Alvin and Marge Schortmann, the hundreds and hundreds of friends that went through your portals in the small New England city of Easthampton, Mass. in search of mineral treasures, wish you well.

There is yet hope for Ivigtut, Greenland, minerals. John Sinkankas, a navy flier during W.W. II, thinks the best of the material is still available with a bit of work. His letter to us, with the accompanying sketch, is concise and self explanatory. Here it is:

Dear Neal:

As usual your column in *Mineralogical Record* was read with great

continued in next column

interest. You mention the passing of Ivigtut—but don't despair—all it needs is someone to go there to look for more, and I can tell you just where it is.

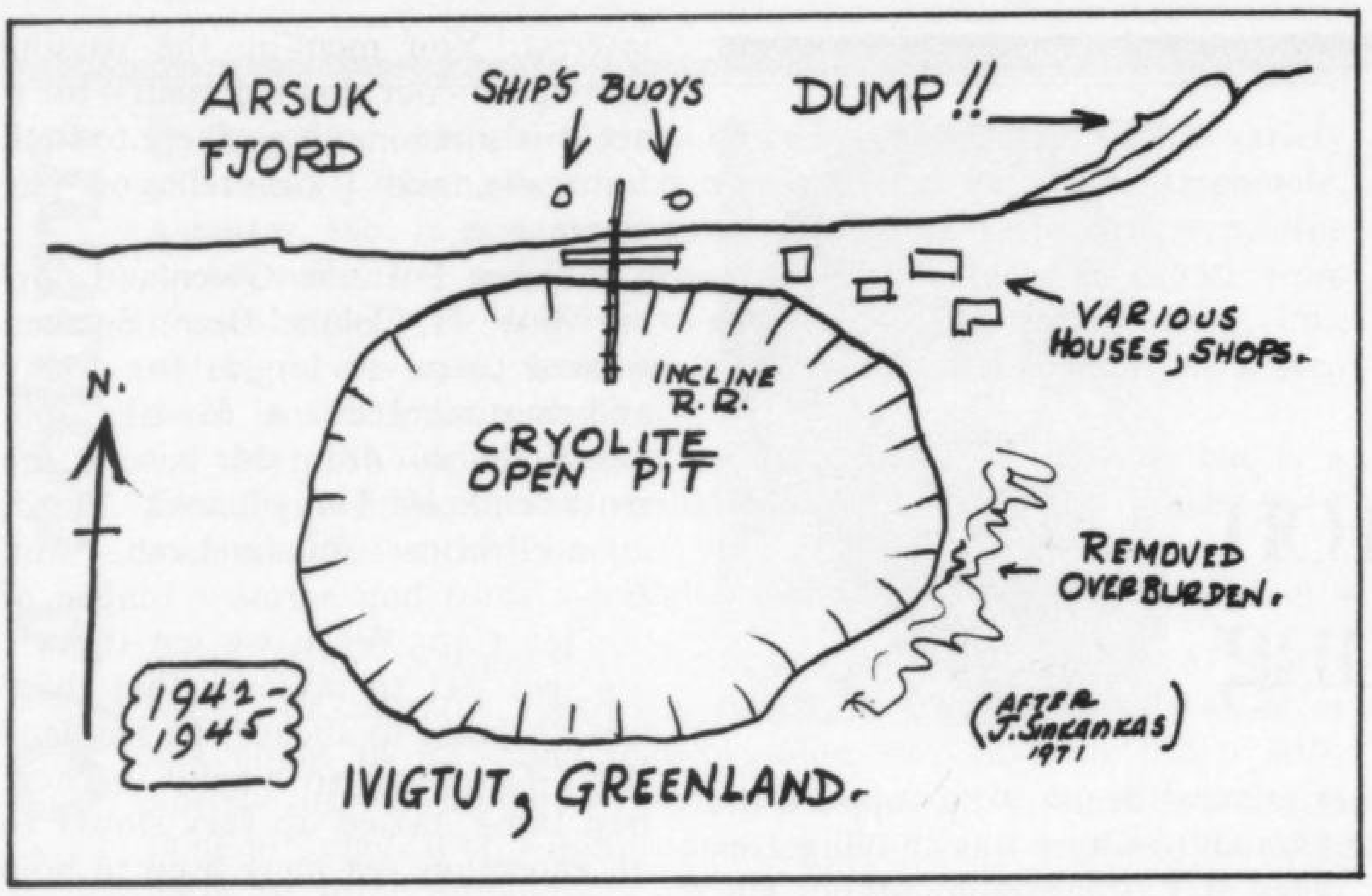
When I was in Greenland during W.W. II, Colonel Bernt Balchen wanted to go to Ivigtut for a day and buttonholed me for the job. The flight was from our base at the inner end of Tunigdliarfik Fjord, inland from Juliaanehaab, and just a short hop across a tongue of the Ice Cap. When we got there I was put out to discover that there was no place to anchor the seaplane (PBY-Catalina), so we did the next best thing, taxied up very slowly to an enormous sea buoy used to hold the cryolite vessels in position off the precipitous beach (of rocks) while they were being loaded from an overhead loader, and tied up to it. A Coast Guard cutter that happened to be there came over with its whaleboat and took us in. I found out right away that there was no collecting in the pit, and actually I was not particularly interested because it was all just a mass of pure white cryolite, and naturally uninteresting mineralogically. Instead I found just to the east of the installation along the fjord edge a grass-overgrown ancient dump which contained the "crud" worked off the surface of the pegmatite body to expose clean ore beneath.

This dump is still there! Probably it has more of interest mineralogically than the later mine ever had. All of it was cryolite beautifully contaminated with the accessory minerals that you mention in your article. Because of the severe climate, it is covered only by a thin coating of easily-dislodged grass! It falls off into the deep water of the fjord which brings to mind the intriguing possibility of another Laurion situation, except this time applied to the cryolite and accessory minerals! (Shown on p. 102)

The sketch herewith is from memory, but I think is accurate enough so that one could find the dump with no trouble at all. At least, when I was there, I spotted it at once as a dump, and so it proved to be.

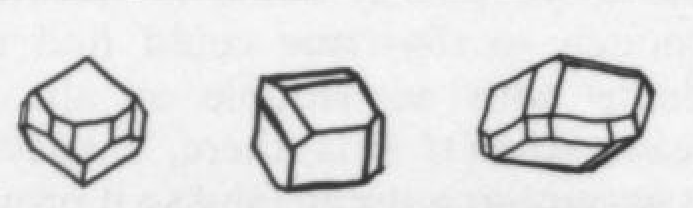
John Sinkankas

Since we live in New Haven, Conn., we frequently drop in to visit



Dr. Horace Winchell at Yale. On a recent call we noted the work of Anneliese Delmonaco, curator of the Yale mineral collection, who has been going through tons of material gathered over the years, cataloging and bringing order out of the mass of stuff stored for "future study." Among other things we noted trays of minerals from Mt. Antero, Colorado collected by George Switzer (Now Dr. G. Switzer of the Smithsonian.) during his graduate years at Yale. Switzer had done his masters on this locality, and had collected the summer previous in the pegmatites at Mt. Antero and White Mt. In the assemblage were immense smoky and clear quartzes, albite, fluorite, beryl, bertrandite, muscovite and a profusion of phenacite. The phenacite encrusted quartz, albite, fluorite and muscovite, and ranged in size from pinhead to crystals a quarter inch in diameter and better.

Phenacite, a beryllium silicate, is rhombohedral, occurs in clear crystals, and at Antero the prevailing form is that shown in Dana's textbook, 4th ed, p. 603, diagram 899, and sketched herewith. Another crystal habit for the mineral is prismatic, with penetration twinning, evidenced by a 12 sided prism and a multiple faceted termination.



3 CRYSTAL HABITS OF PHENACITE FROM GOLDSCHMIDT'S "ATLAS DER KRYSTALLFORMEN," WHICH SHOWS 109 FORMS (1920)

We went through our mounted specimens and found a number of localities represented. From the U.S. were mounts from Amelia, Virginia: Intervale and N. Chatham, New Hampshire; Lord's Hill, Stoneham, Maine: and Mt. Antero, Colorado. Foreign localities were represented by specimens from Salzburg, Austria; Llallagua, Bolivia: and from the famous San Miguel Piracicaba locality at Minas Geraes, Brazil, where water clear euhedral crystals up to 4 inches in diameter were found. We do not have any from the Urals, France, Norway, Switzerland or Mexico.

The Amelia, Va. occurrence is most interesting. In 1959, accompanied by Cosminsky and Perloff, we visited the Morefield mine and collected amazonite, which, though green, had pale areas along cleavage cracks. These contained minute sugary clear crystals, some loose, and a few embedded in the green microcline. At about 40X it could be determined that these clear crystals were phenacite. A personal communication with the late Dr. Jewel Glass of the U.S.G.S. confirmed that phenacite occurred thus at Amelia, and was not uncommon. We have several mounts and a small vial with loose xls.

In 1968, at Lord's Hill, Stoneham, Me., an area full of small quartz crystals was uncovered. For the most part these were pale smoky and colorless flattened units, the surfaces of which were completely coated with phenacite, of the usual rhombohedral habit, the crystals embedded slightly in the quartz. Some New England dealers still have supplies of this stuff. The Brick House, Harrison, Me. 04040 supplied us with ours.

We've just returned from the Eastern Federation convention at Lake Placid, New York. A fine meeting, where we caught up with current trends in mineralogy, and obtained a few things that will enhance our m/m collection. Worldwide Minerals, of Quebec, supplied uranocircite in fine yellow platy crystals from Bergen, Vogtland, Germany at a very reasonable price, and then came up with a small specimen (enough for three mounts) of argentopyrite and proustite from Niederschlema, Germany. This latter is a find. The only argentopyrite we'd had was from St. Andreasberg, Harz, Germany, and a rather poor mount, but the new specimen shows prismatic habit, twinning, and conforms to all the visible characteristics described in Dana's System. It is a mineral incompletely described* and may be related to sternbergite, but the habit of the crystals is distinct, and a visual inspection "pinned it down." Other availables: from Sklar—Brazilian pyrrhotite and cubanite, eosphorite and roscherite; from Ron Martin—rutile on muscovite from North Carolina and rathite in dolomite from Binnenthal, Switzerland; from Allison—crystals of malachite from North Carolina and good strengite from Alabama; from Malenson—beautiful green fibrous clusters of "honessite" (pseudomorphic after millerite) from Hall's Gap, Kentucky; and lastly, from Prosper Williams—green chrome grossular from Asbestos, Quebec, made up of a core crystal of green garnet (perhaps uvarovite) covered by an outer layer of clear grossular. All in micromount size. All beautiful.

Francis Paul (see ad inside cover) has just received some copies, in English, of *The Minerals of Greenland.*

Buy and use two mineral books this month.
Neal Yedlin

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*Ed. note—According to Czamanske and Larson, *Amer. Min.*, **54**, 1198-1201, 1969, argentopyrite and sternbergite are chemically identical but differ crystallographically and are therefore dimorphs.

Photo by O. D. Smith, LaJolla Calif.

Personality Sketch

John Sinkankas

by Dona Leicht

Hundreds of thousands of visitors each year view the Smithsonian's Hall of Gems and Minerals, where some of the more noteworthy attractions include faceted gems by John Sinkankas. Like the facets of these gems, those of John Sinkankas are many and varied—author, lecturer, artist, aviator, collector, lapidary and mineralogist. To discuss in depth the personality of John Sinkankas would take more time and space than is available here, so brief, but revealing, glimpses of what makes this gentlemen so special in the field of mineralogy will have to suffice.

His childhood days began in Paterson, New Jersey (an appropriate spot to begin an interest in minerals), where a fondness for everything connected with nature naturally led to his discovery of minerals. It is a delight to listen to John reminisce about early collecting days at now famous Paterson localities, such as the Prospect Park and New Street quarries. Specimens collected in boyhood days were donated to the Paterson Museum, with whom he had a close relationship.

His love of minerals was shared by his love of flying which eventually led to his making his own glider. He laughingly tells of the time on one test flight when he nearly beheaded a cyclist in his path, where upon John's father called a halt to his flying career, at least for the time being.

After graduation from Paterson State College in 1936, he joined the Navy and embarked upon a distinguished career in Naval Aviation. Beginning as an Aviation Cadet, he rose through the ranks to Captain, U.S. Navy. His interest in minerals did not wane during this career, except during the war years. He managed to visit many localities throughout the world and tells of a particularly interesting trip to the famous Ivigtut, Greenland cryolite mine (see *Yedlin*, this issue, p. 101).

An active resumption of the study of minerals and gems began in 1947 when he took up lapidary work. The lack of any authoritative work on the subject forced him to teach himself the art, thus learning by trial and error the best ways to cut gems. At this time he began a systematic investigation of the cutting properties of a large number of gemstone species. In 1955 his first book, *Gem Cutting—A Lapidary's Manual*, was published. A second edition was published in 1962 and is still considered one of the finest books in its field.

Among major lapidary works in the Smithsonian are a 7,000-carat faceted "egg" of rock crystal, mounted on a gilt silver stand studded with multicolored Montana sapphires; a 4,500-carat pale smokey quartz "egg"; and a 3,273-carat Brazilian topaz of soft blue color to mention several. To enable him to do this "giant size" work, he had a special faceting machine made which is one and half times normal size. John's work is also represented in the American Museum of Natural History in New York, and the Royal Ontario Museum in Toronto.

Lack of any comprehensive publication on gemstone localities in North America (since Kunz, 1890) led to writing *Gemstones of North America* in 1959, now ranked as the standard work on the subject.

After 25 years of service, Captain Sinkankas retired from the Navy to San Diego, California in 1961, with his wife, Marjorie, and four children.

Self-taught in lapidary work, he is also self-taught in mineralogy. His sincere interest in promoting and encouraging amateur mineralogists produced several more books: *Gemstones and Minerals: How and Where to Find Them*, 1961, and a second edition in 1970 under the title *Prospecting for Gemstones and Minerals; Mineralogy for Amateurs*, 1964; *Mineralogy: A First Course*, 1966; and *Standard Catalog of Gems*, 1968. A new book, a compilation of useful information in the mineralogical and lapidary areas, is in preparation, and will be published early next year. From the writer's brief examination of the rough draft, it promises to be a book which will again be of great benefit to the amateur collector. It is interesting to note that John does all of the line drawings, sketches and color paintings for his books.

Over the years, he has contributed articles to many periodicals dealing with gems and minerals. In 1956 he discovered and identified hambergite from the Little Three mine at Ramona, California, the first reported occurrence in the Western Hemisphere. Recently, he identified, and plans to describe, the white to glassy incrustations on Mexican stibiconite (pseudomorphs after stibnite) as stibiconite in a very pure form hitherto unreported in any literature, and as euhedral crystals which also have not been hitherto reported.

A visit to the Sinkankas home is a memorable experience. The mind boggles at the collection of exquisite minerals (many of which are self-collected) and undoubtedly one of the most extensive libraries in the world dealing exclusively with gems and minerals. There are over 3,500 volumes on the shelves and many thousands of reprints on file. His library on gems may be the best in the world, containing more volumes on that specific subject than any museum, the U.S. Library of Congress, private collection, etc. Of particular interest in this phenomenal book collection are no less than 25 editions of Pliny's (Roman, A.D. 24-79) *Historiae Naturalis*, nine editions of Tavernier's *Voyages*, all the editions of Boetius de Boodt, and many others that are now classics in the field.

His memberships include the Cosmos Club of Washington, D.C.: honorary member of San Diego Mineral and Gem Society: Fellow, Mineralogical Society of America: Associate Gemologist, American Gem Society: Executive Committee member - Friends of Mineralogy.

Currently, John is associated with Scripps Institute of Oceanography of the University of California, San Diego as a Research Assistant in Mineralogy. He is actively engaged in work on moon rock samples. He is also occasionally a lecturer in mineralogy at San Diego State College. Even with this obviously busy schedule, he makes numerous speaking engagements at various societies in the Southern California area.

There is no gauge by which one can measure John Sinkankas' contributions toward making mineralogy an interesting, stimulating, understandable and enjoyable pastime, or profession, for many people. Those of us who pursue an interest in minerals are indeed fortunate to have him among us.

Rhodochrosite Crystal Localities in the West

Harold W. Miller, Boulder, Colorado

Rhodochrosite, $MnCO_3$, is a common gangue mineral associated with epithermal and particularly mesothermal lead-silver deposits. Good crystals, however, are very rare in the U.S. and occur only in Colorado and Montana.

Few specimens are as highly prized by the discriminating mineral collector as a fine group of rhodochrosite crystals. The variation in crystal size, habit, color, associated minerals, and matrix is so great that a single collection might well contain a dozen or more rhodochrosite specimens without exhibiting a monotonous array. This is particularly true of Colorado specimens, all of which are so different in appearance as to have a personality of their own, yet so similar as to be recognized immediately as originating in Colorado.

An observant collector should, in time, be able to recognize on sight not only the state in which a particular rhodochrosite group originated, but the mining district, and even the mine from which it was removed. Of course this is best accomplished by actually visiting the mines and the mining camps. If this is not possible the collector must scrutinize every specimen available to him either in a dealer's stock or in a museum, keeping in mind the fact that these specimens are commonly misidentified. I have frequently seen specimens, which were obviously from Butte, Montana, identified as being from Colorado. These specimens were certainly equal in quality and could be appreciated aesthetically but the scientific value of a mislabeled specimen is minimal.

I hope to be able, in the next few pages, to point out some of the identifying features of rhodochrosite specimens, which will assist the collector in determining at least the mining district from which a particular crystal group originated. Collecting-localities will also be described, although it is not my intention of giving detailed directions. Any good collector should need only the name of the mine and the mining district.

There is no secret as to the method of identification of the source of a mineral specimen. All that is required is careful observation and a good memory. In brief, a suggested method of observing and mentally cataloging the salient features of a mineral specimen, in this case rhodochrosite, is as follows:

CRYSTAL HABIT. Are the crystals rhombohedra, scalenohedra, or some combinations of these forms?

CRYSTAL COLOR. Are the crystals milky-pink, deep red, opaque, translucent, or transparent?

MINERAL ASSOCIATES. Are the crystals associated with galena, sphalerite, silver, gold, tetrahedrite, molybdenite, rhodonite, calcite, quartz, or fluorite? What is the color of the fluorite? Is the calcite manganocalcite? Are the associated minerals crystallized? If so, what crystal habits are exhibited?

PARAGENESIS. What is the time sequence of mineral deposition? For example, did quartz deposit before or after rhodochrosite? If it deposited before the rhodochrosite, the matrix will be quartz. Occasionally rhodochrosite crystals will be perched on a matrix of quartz and quartz crystals will be perched on the rhodochrosite crystals. In this case, quartz was deposited before and after the rhodochrosite. Apply this method to other mineral associates such as pyrite, sphalerite, galena, etc.

MATRIX. What is the matrix? Sometimes much can be learned by turning the specimen over and looking at the back. Perhaps the matrix is massive rhodochrosite or quartz. It may be volcanic rock such as rhyolite or quartz latite. On the other hand, the rock may be plutonic, such as monzonite. The matrix might even be galena or sphalerite. In many cases the matrix may very well be the deciding factor as the the source of the specimen.

It is necessary to utilize all of these characteristics in the identification of the source of a specimen. There are variations on any one or more criteria in any one mine, but a careful consideration of all five criteria is nearly foolproof.

Colorado Localities

The Colorado mineral belt, a region of rugged mountains and thousands of mines, extends southwest from Boulder County to La Plata County in southwestern Colorado. Rhodochrosite crystals have been found in numerous localities over the entire extent of the mineral belt, with the possible exception of Boulder County. Probably the finest specimens have been found in the high, precipitous peaks of the Mosquito Range, which is located in the center of the mineral belt. In this rugged area such famous mines as Climax, John Reed, Sweet Home, Tanner Boy, Russia, and many other sources of good crystals are located.

One of the most recent finds of excellent crystals has been in the Urad mine on the crest of the Continental Divide near Berthoud

Pass. These crystals are very large, deep red, and in many cases transparent (Fig. 1). In my opinion, the quality of the Urad specimens is equal to that of the much sought-after Sweet Home specimens. As a matter of fact, a few have been sold as Sweet Home rhodochrosites. Unfortunately these fine specimens are very rare and have been obtained only while developing the mine by drifts and raises. When actual large-tonnage mining operations for molybdenum commence, very few crystals will survive.

Fig. 1. Deep red, transparent rhodochrosite rhombohedra 1-1/2 inch on an edge with milky quartz crystals. Associated sulfides are pyrite and molybdenite. Specimen size 4 x 6 inches. Urad mine near Berthoud Pass, Clear Creek County, Colorado. H. Miller Collection. Photographed by Gordon E. Sweeney. ▶

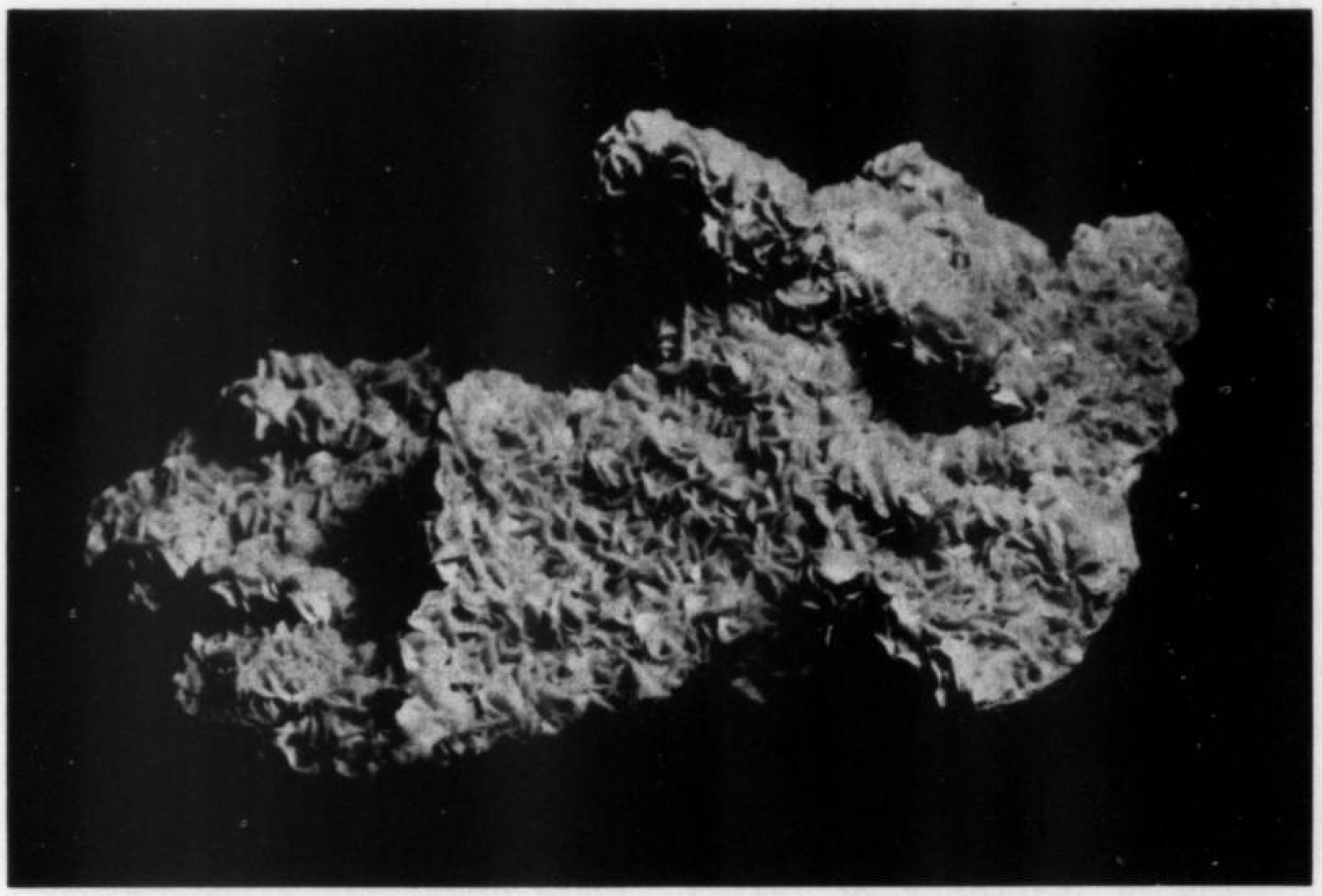
About a mile southeast of the summit of Fremont Pass a dirt road goes to the east, past the Climax Molybdenum mill, and heads up Alicante Gulch (Fig. 2). If one proceeds about a half a mile along this road the black manganese-stained dumps of the John Reed mine are readily visible. Very fine deep red, transparent specimens of rhodochrosite have been obtained here. If some of the large black rocks on the dump are cracked open, fine red specimens may still be obtained from small vugs. Exposure to moist acid-laden air can turn the finest specimens black in a very short time. This is particularly true of the mines at Butte, Montana. All is not lost, however, for if a good but blackened specimen is found, the oxide coating may be removed without damage to the spcimen. Just immerse it in water, add a few drops of hydrochloric acid and a few milliliters of ordinary 3% hydrogen peroxide, obtainable at any drug store. There will be a great deal of fizzing and the black stain will disappear leaving an undamaged red specimen. Be sure not to add too much acid, as this will destroy the rhodochrosite.

Fig. 2. View up Alicante Gulch towards the John Reed mine, source of excellent red transparent rhodochrosite crystals, Lake County, Colorado. Part of the Climax Molybdenum mill can be seen in the foreground. ▶

Fig. 3. View to the west toward Leadville and a gallows frame outlined against Mt. Elbert (14,431 feet). The Julia Fisk mine is about a mile from here. ▶

About 12 miles to the southwest of Alicante Gulch is the famous silver camp of Leadville (Fig. 3). The city is located at an altitude of over 10,000 feet on the western slopes of the Mosquito Range. It was while working at Leadville that

Fig. 4. Pinkish-lavender, opaque rhodochrosite scalenohedra 1/4 inch across. Matrix consists of massive rhodochrosite with galena and sphalerite. Specimen size 3 x 6 inches. Julia Fisk mine, Leadville, Lake County, Colorado. H. Miller Collection. Photographed by Gordon E. Sweeney. ▶



I began to realize the potential of this area as a source of really fine crystals—brilliant pyrite cubes nearly a foot on an edge from the Little Jonny mine, wire silver, gold, bright galena crystals, and so on. The Matchless mine produced some very fine wire silver with pink rhodochrosite scalenohedra perched on and pierced by the wires. The Julia Fisk mine produced fine pinkish-lavender groups of scalenohedra, often with bright galena cubes (Fig. 4). I think, however, that I saw the finest specimen in the world, one cold winter evening, in a Leadville bar. A miner had just come down from the Climax mine, located on Fremont Pass at over 11,000 feet. Spotting me at the bar he came over and placed his lunch pail in front of me. In that pail was the most spectacular specimen I have ever seen—an absolutely perfect rhodochrosite rhombohedron about 2 by 3 inches, perched on a matrix of drusy white quartz. The crystal was absolutely transparent and could not possibly have been a deeper red color. This prize came out of the Climax mine. It is not often that a crystal can survive the block-caving methods of mining employed at Climax. It was probably obtained from a drift or a raise. Unfortunately, all attempts at obtaining this specimen failed; the miner has long since moved on to other mining camps.

Spectacular specimens of rhodochrosite have been mined on the east slope of the Mosquito Range, just over the hill from Leadville. The Sweet Home mine, located at the lead of Buckskin Gulch, produced the most sought-after specimens. Similar specimens were obtained, however, from the Tanner Boy mine on the southwest side of the gulch, and from the Russia mine at an altitude of nearly 14,000 feet on the east face of Mt. Lincoln. All of these mines have produced deep red gemmy rhodochrosite crystals; frequently accompanied by pink, blue, or green fluorite octahedra.

▲

Fig. 5. View west towards Gladstone and McMillan Peak (12,900 feet), San Juan County, Colorado. The mines in this area produce some of the finest rhodochrosite and huebnerite crystals in the world.

About one hundred miles southwest of Leadville is the Bonanza mining district, located in Saguache County. This area is known for the occurrence of the rare telluride minerals, rickardite and empressite, as well as rhodochrosite. Slightly warped rhombohedra of deep pink or rose red color are found only in some of the veins in the southern part of the district. In both the Eagle vein and the Rhodochrosite vein of the Express mine, green fluorite is a common accessory mineral. In the Clark vein of the Rawley tunnel nearly pure rhodochrosite occurs associated with manganocalcite. Occasional small vugs in the ore of the Eagle mine contain many small prismatic crystals of red ruby silver (pyrargyrite) perched on rhodochrosite crystals. Wire silver also occurs with the rhodochrosite.

In many respects, the specimens from this area resemble those from

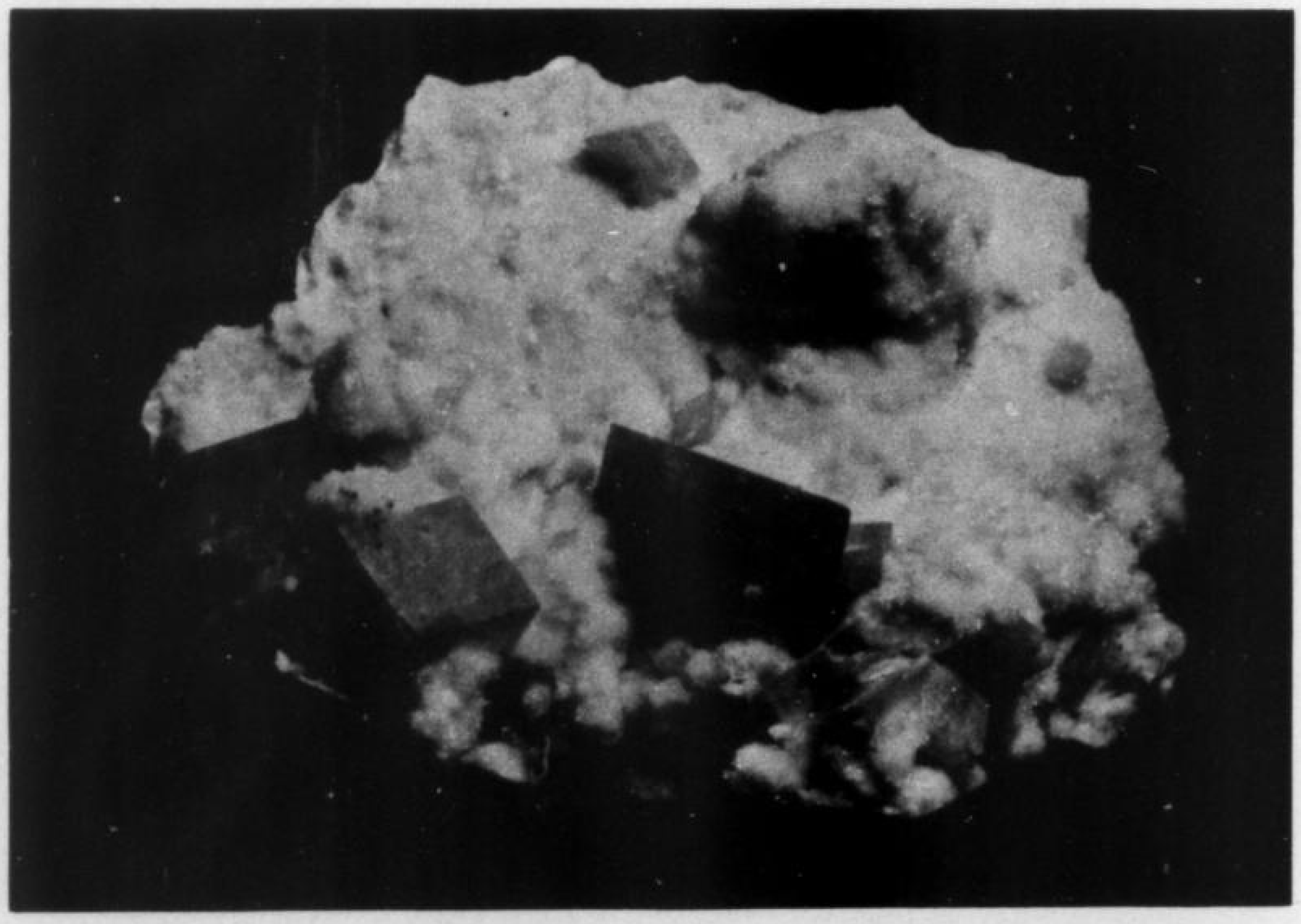
Montana. The rhodochrosite occurs as opaque milky-pink aggregates of rhombohedra on massive rhodochrosite, as at Butte. The difference, however, is the presence of green fluorite and an apparent matrix of latite rather than quartz monzonite. At Philipsburg, Montana, just west of Butte, rhodochrosite occurs with red ruby-silver crystals. In this case, however, the silver mineral is proustite.

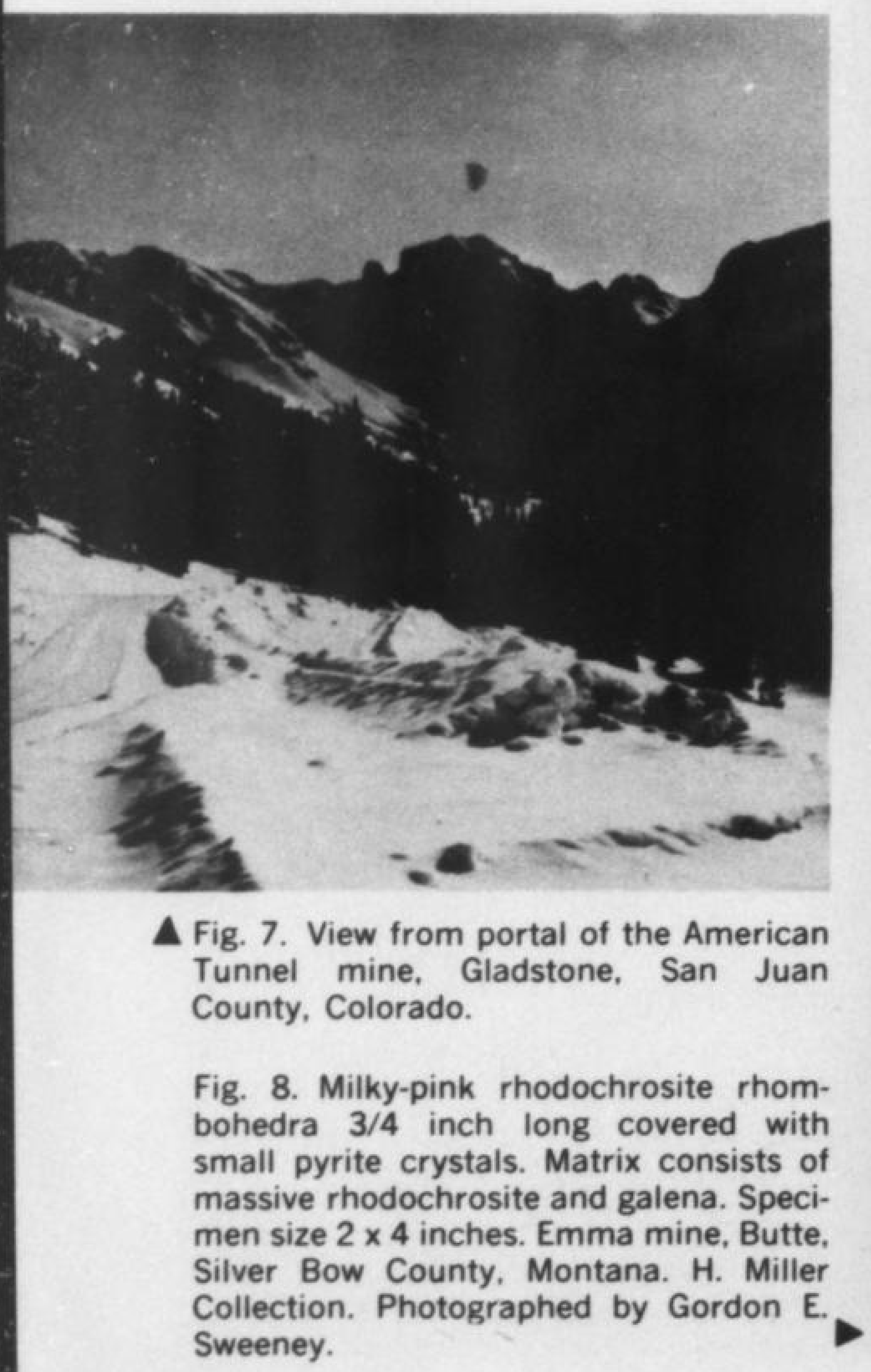
Continuing to the southwest along the mineral belt one comes to the picturesque mining camp of Silverton, high in the rugged San Juan mountains. This area is the source of many fine crystals of enargite, tetrahedrite, huebnerite, and rhodochrosite.

Early in the spring of 1955 I made a trip to Silverton with Al Erhard, a prospector friend of mine. We were looking over a large collection of gold specimens one night when we met a miner by the name of Haywire Orten. Haywire was operating the Red Bonita tungsten mine near Gladstone. Since Al and I were interested in a tungsten property in Montana at that time we had a great deal to talk about. Finally, as the night passed on, Haywire pulled out an old powder box which contained some mineral specimens, drill bits, assorted junk, and three of the finest crystallized huebnerite specimens that I had ever seen—beautiful mahogany-red crystals 3 to 4 inches long and standing upright in matrix. There was no way that I could get those specimens from Haywire that evening. I was not about to give up, however, and returned to Butte a week later to describe these crystals to a friend of mine, Ed McDole, tramp miner and mineral collector without equal. He went to Silverton and got them for me. In later years he mined many fine huebnerite crystals and groups from the Red Bonita, Adams, Kitty Mac, Yukon, and Anglo Saxon mines. I believe, however, that Al and I were the first to make these fine crystals available to museums and collectors.

In recent years the Silverton-Gladstone area (Fig. 5) has become famous again as a source of rhodochrosite crystals. Most of these came from the lower levels of the American Tunnel at Gladstone (Fig. 7). The first specimens to come out were small light pink rosettes of scalenohedral rhodochrosite crystals with milky-white quartz and green fluorite. Later, large deep red rhombohedra up to 2 inches on an edge were obtained

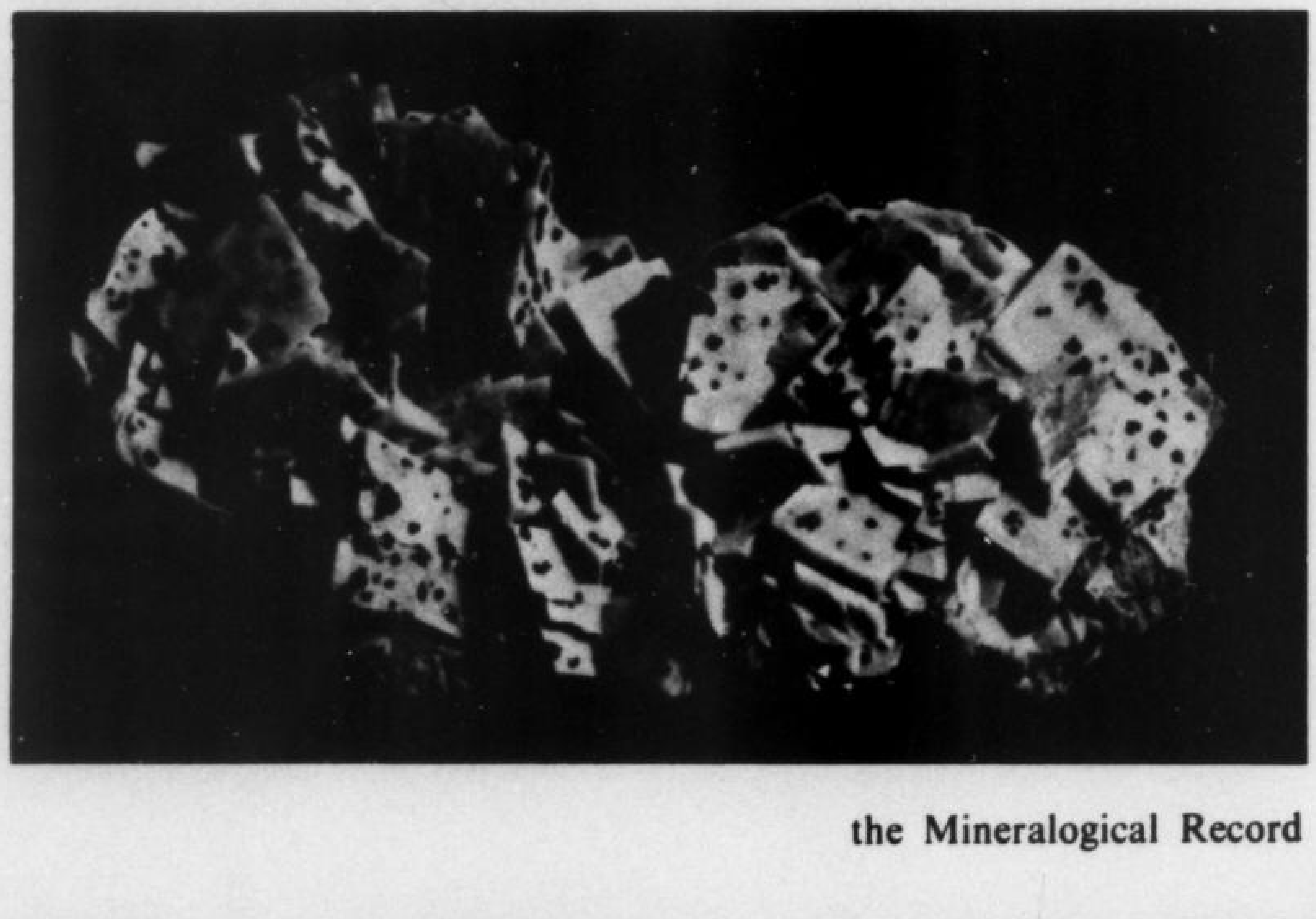
Fig. 6. Rose-red, transluscent rhodochrosite rhombohedra 1 inch long on drusy, milky-white quartz matrix. Matrix size 3 x 5 inches. American Tunnel mine, Gladstone, San Juan County, Colorado. H. Miller Collection, Photographed by Gordon E. Sweeney. ▶





▲ Fig. 7. View from portal of the American Tunnel mine, Gladstone, San Juan County, Colorado.

Fig. 8. Milky-pink rhodochrosite rhombohedra 3/4 inch long covered with small pyrite crystals. Matrix consists of massive rhodochrosite and galena. Specimen size 2 x 4 inches. Emma mine, Butte, Silver Bow County, Montana. H. Miller Collection. Photographed by Gordon E. Sweeney. ▶



(Fig. 6). Most of these were associated with drusy quartz but often fine large crystals were found, perched on galena or sphalerite. I have one specimen which exhibits an interesting history of the chemical and physical conditions as they varied in the vein during ore deposition. The first mineral deposited was an iron-rich black sphalerite. Large red rhombohedra of rhodochrosite were then deposited on the sphalerite. Conditions in the ore solutions changed and minute milky-white quartz crystals coated the rhodochrosite, but not the sphalerite. This was followed by another change in the hydrothermal solutions and light pink scalenohedra of rhodochrosite grew on the quartz but not the sphalerite.

If space permitted, many other Colorado localities could be described. Any good collector, however, should be able to ferret them out for himself. After all, that is half the fun of collecting.

Montana Localities

In the fall of 1955 Butte was an exciting city. The price of copper was high and miners were arriving daily from every mining camp in the west. Butte was known then as the Capital of the "tramp miner." Many of the good crystal-producing mines were in production. The East Colusa and the Leonard, near Meaderville, were producing fantastic crystal groups of enargite, pyrite, covellite, digenite, and colusite. The Emma mine, in "down-town" Butte, was producing rhodochrosite specimens by the hundreds.

One overcast November day I received word from Ed McDole that he had something special to show me. I knew that this had to be good or Ed would not have taken the trouble to call. Arriving in Butte shortly after shift change I hurried up the street, past the Emma mine, to the Old Lincoln Hotel where Ed resided. The whirring and clanging of the sheave wheels at the tops of the numerous gallows frames added to the excitement. At that time many operating shafts were in down-town Butte. Making my way up the dimly lighted staircase I arrived at Ed's room to be greeted by, "Hello, Miller, you old bounder, how are you? If you can guess what I have here I'll buy your supper." Ed reached for a cigar box on top of a pile stacked near the door and cautiously opened it to reveal three specimens about 3 by 3 inches covered with euhedral crystals, somewhat less than 1/4 inch long, of a mineral which I did not recognize. I lost by chance for a free supper, but it was worth it. A pocket of digenite crystals had just been opened up and these were among the first to come out. Digenite crystals have never been common at Butte, as a matter of fact even the massive ore is rare. Years later, however, Ed visited me in Colorado and revealed the best of all the Butte digenites—a single crystal about 1 by 1/2 inch perched on a quartz matrix. I doubt that its equal exists anywhere in the world.

That same evening Ed showed me a few fine rhodochrosite crystals of a type not common in Butte. These were deep red, transparent 1/4 inch rhombohedra with milky white quartz rosettes. They could be confused with Colorado specimens, but at that time rhodochrosites were not coming out of

Fig. 10. Milky-pink, opaque, rhodochrosite rhombohedra with quartz crystals. Rhombohedra 3/8 inch long. Matrix consists of massive rhodochrosite, quartz, and pyrite. Specimen size 4 x 5 inches. Emma mine, Butte, Silver Bow County, Montana. H. Miller Collection. Photographed by Gordon E. Sweeney. ▼

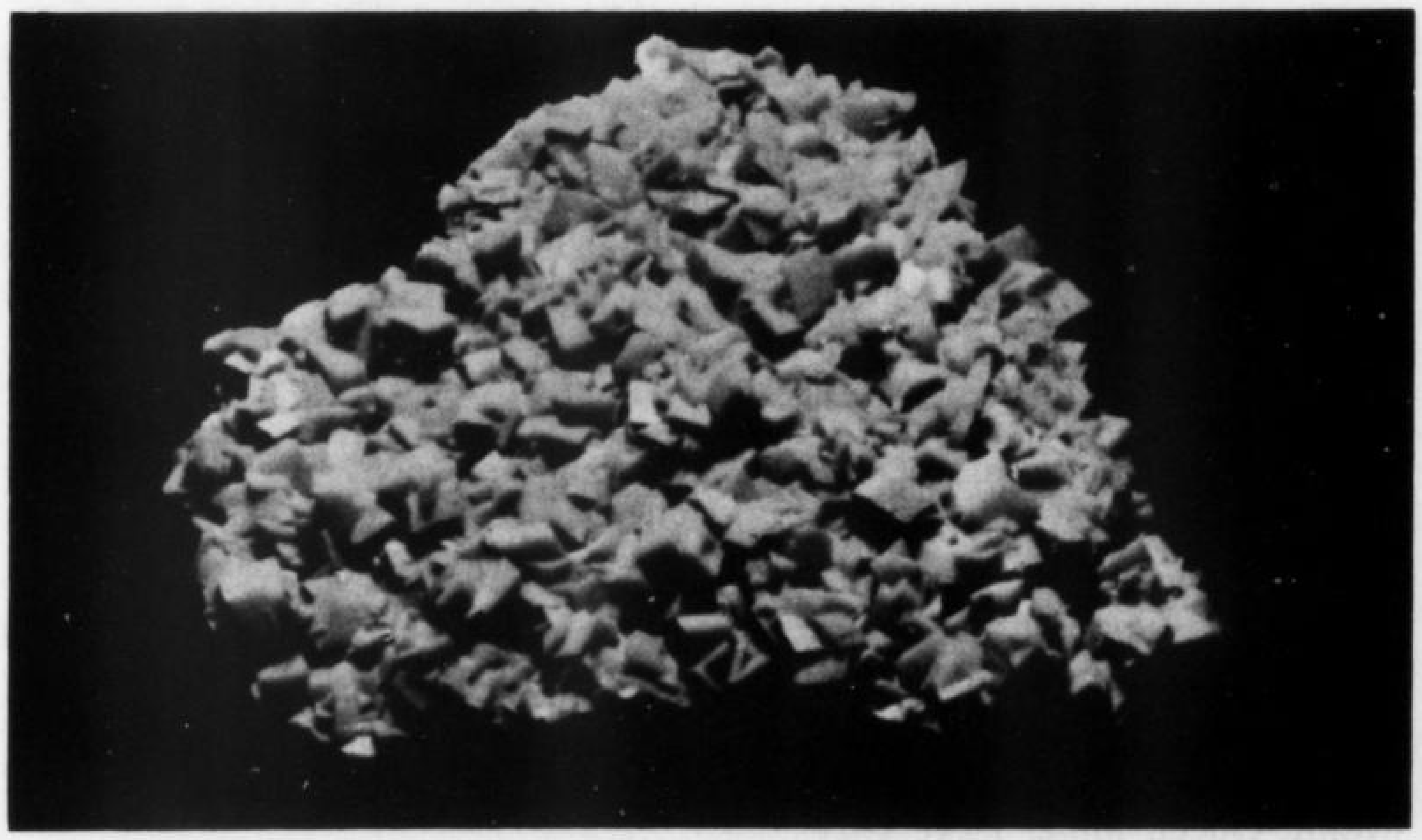
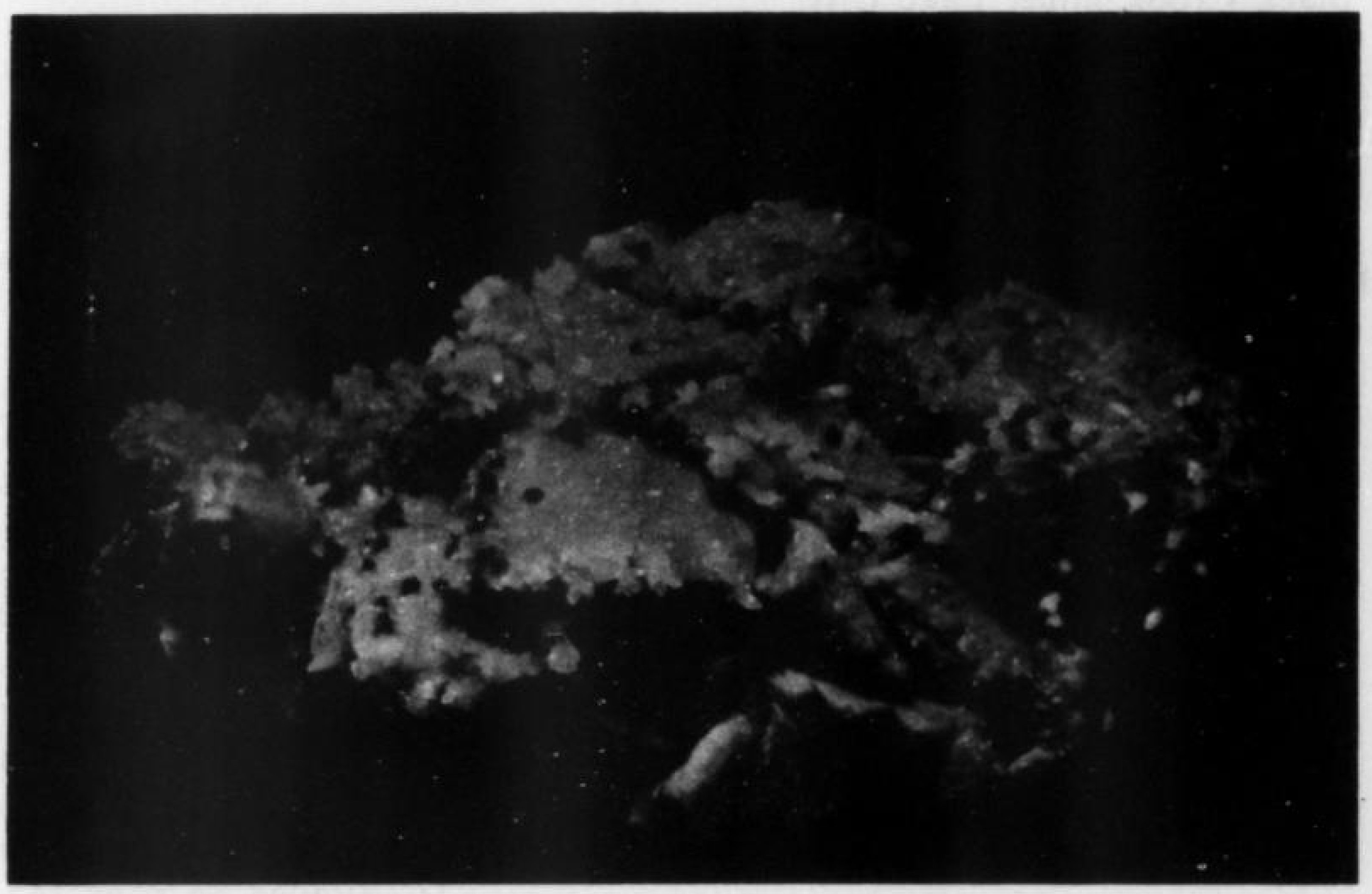


Fig. 9. Milky-pink, opaque rhodochrosite crystals 1-1/4 inch long. Minute quartz and pyrite crystals cover this specimen. Matrix consists of altered quartz monzonite and pyrite. Specimen size 3 x 5 inches. Travona mine, Butte, Silver Bow County, Montana. H. Miller Collection. Photographed by Gordon E. Sweeney. ▶



Colorado. The main source of rhodochrosite at Butte in those days was the Emma mine. These were fine rhombohedra up to 3 inches on an edge and of an opaque milky-pink color (Figs. 8, 10). Frequently milky white quartz crystals and minute pyrite crystals accompanied these groups. Some fine red specimens came from the Travona mine (Fig. 9) and a few lavender crystal groups came out of the Elm Orlu mine.

There is one other rhodochrosite locality in Montana: the mining camp of Philipsburg, Granite County, about 60 miles west of Butte. A few fine transluscent rose-pink rhombohedra came from the Algonquin mine in the valley of Frost Creek. One specimen in Ed's collection is covered with small prismatic, bright red, proustite crystals.

Rhodochrosite Crystal Occurrences in Colorado

There are, without doubt, many other occurrences of rhodochrosite crystals in Colorado. Some of the mines have produced better specimens than those described. The descriptions and localities given below are those of specimens actually seen by the author in mines, assay offices, private collections, and museums.

Chaffee County	
Banker mine, Winfield district	Pale pink, opaque scalenohedra. Close to manganocalcite.
Mary Murphy mine, Chalk Creek	Small (1/4 inch) pink crystals of gem quality.
Clear Creek County	
Gomer mine, Georgetown	Ferruginous crystals covering galena crystals.
Hedensburg mine, Georgetown	Large crude opaque pink crystals up to 2 inches across and on massive rhodochrosite.
Urad mine, Berthoud Pass	Excellent, deep red, gemmy crystals up to 2 inches on an edge with white quartz crystals and molybdenite. Equal in quality to those from the Sweet Home mine.
Gilpin County	
Bellman mine, Central City	Good 3/4 inch deep red crystals.
Gem mine, Central City	"
Moose mine, south side of Willis Gulch about one mile south of Central City	Excellent one inch, bright red rhombohedral crystals of gem quality with purple fluorite crystals and pyrite.
Hinsdale County	
Hidden Treasure mine Lake City	Pale pink crystals up to 1 inch across and associated with freibergite. These crystals bleach on exposure to sunlight.
Monte Queen mine, Lake City	"
Black Crook mine, Lake City	"
Ulay mine, Lake City	"
Lake County	
A.Y. and Minnie mine, Leadville	Pale pink to violet scalenohedra about 1/4 inch long.
Mammoth mine, Evans Gulch	--
Julia Fisk mine, California Gulch	"
Matchless mine, Leadville	Pale pink scalenohedra perched on wire silver.
John Reed mine, Alicante Gulch	Deep rose-red, gem quality crystals to 3/4 inch across.
Climax mine, Fremont Pass	Superb deep rose-red, gem quality crystals to 3 inches across on white quartz.
Ouray County	
Mountain Monarch mine	Rose-red, gemmy crystals about 1/2 inch long.
Silver Bear mine	"

(Continued on page 143)

The State of the Art X-Ray Crystallography—Part II: Single Crystal Methods

By Joel E. Arem

The usefulness of X-rays in determining the internal structure of crystals is based on two factors: a) crystals are periodic 3-dimensional arrays of atoms, ions and molecules, and b) X-rays comprise a portion of the electromagnetic radiation spectrum whose wavelengths are similar in magnitude to the spacings between the atoms. To fully understand and appreciate the crystallographic applications of X-rays, one must consider three separate topics. These are: 1) generation and properties of X-rays 2) interaction of X-rays with matter, specifically solids 3) detection of scattered X-rays and interpretation of observed effects.

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1. Generation and properties of X-rays

When X-rays were first discovered by Röntgen in 1895, their true nature was a complete mystery, hence the designation "X." The strange new radiations were known to be very penetrating, since they exposed photographic film encased in black paper and thus shielded from light. Imagine Röntgen's shocked surprise when he first saw shadows of bones in his own hand, cast upon a fluorescent screen by rays from one of his experimental high energy cathode tubes! Gradually, X-rays began to be better understood, and the danger of direct exposure to them was realized. We may never know how many scientists died of radiation damage sustained in early experiments, but the number surely is not small.

The most critical problem regarding X-rays, faced by physicists in about 1900, was the actual constitution of the rays. Were they waves, or were they streams of particles? Much evidence could be given supporting either explanation. The Laue experiment, described in Part I (Mar.-April, 1971) of this article, seemed to settle the controversy once and for all in 1912, in showing that X-rays could be diffracted by crystals. Diffraction is a phenomenon generally acknowledged to be characteristic only of waves.

In recent years the distinction between wave and particle behavior has, in some cases, been shown to be not very clear-cut. The quantum theory of Max Planck tells us that energy, in the form of light and other so-called *electromagnetic radiations,* is transmitted through space in small "bundles" or "wave packets" called *quanta.* The duality in behavior previously noted for certain types of radiation could then be explained as due to the measurement procedures used. In some experiments the wave-like nature is more pronounced, and in others the particle characteristics are dominant; but both types of properties are inherent in electromagnetic radiation effects. Thus, it should not be confusing to read about the number of "X-ray quanta" (particle behavior) in a pulse of X-rays of a given wavelength (wave property).

What, then, gives rise to X-rays? How do they differ from other types of radiation? To answer these questions we must examine the structures of atoms themselves.

When sodium or a salt of this metal is heated in a flame or by electrical resistance in a special type of lamp, it gives off an intense yellow light. This yellow color is characteristic of the *emission spectrum* of sodium. Many other metals similarly exhibit characteristic colors when heated.

If this were not so, fireworks displays would indeed be dull and uninteresting! The red of strontium, the violet of potassium, green of barium and blue-green of copper are all characteristic flame colors, and are caused by the stimulation of electrons belonging to the metal atoms. The electrons are *excited* by the heat of the flame and jump to positions of higher energy; to do so, however, they must absorb energy from the flame. When the electrons return to their original positions this energy is given off in the form of light of a specific color—that is, of a specific wavelength. This is the characteristic flame color for the metal, and it depends on the electrons involved and the amount of energy needed to excite them.

Other forms of energy than a flame can be used to excite the outer electrons of atoms, resulting in a variety of effects. One of the more familiar of these effects is fluorescence, in which the customary energy source is ultraviolet light. Ultraviolet (UV) light comprises a range of wavelengths (Fig. 1), hence the distinction between "long wave" and "short wave" UV, but all UV wavelengths are invisible to the human eye. Ultraviolet light is energetic enough to excite electrons in certain types of materials, called *phosphors,* that have been "sensitized" by chemical impurities or structural defects. When excited electrons in a phosphor return to their former levels, some of the energy they release in the process is lost as heat. The remaining energy emitted is therefore less than the absorbed light energy. As *Fig. 1* shows, lower energies correspond to longer wavelengths, and so if the emitted light is in the visible spectrum, we observe a fluorescent color. The delay or afterglow seen in phosphorescent materials is due to a delay in the return of the excited electrons to their original positions. The longer they take, on the average, to drop back to an unexcited state, the longer the phosphorescence.

The relationship between energy and wavelength is an easy one to understand, when it is realized that the nucleus of an atom, with its positive charge, strongly attracts the negatively charged electrons spinning around it. Electrons closer to the nucleus are attracted more strongly than those further away. To move an electron away from the nucleus one must overcome the attraction, and this requires energy. This energy is given up by the electron when it returns to its original position. Electron orbits at different distances from the nucleus can therefore be assigned specific *energy levels;* the "jumps" of electrons between energy levels are called *transitions.* Electrons can move only between energy levels that are characteristic of each type of atom, and thus only specific, discrete amounts of energy can be absorbed and emitted by electrons in changing positions within atoms. Electron transitions are therefore said to be *quantized,* because they involve **units** of energy, called *quanta.*

We may think of electromagnetic radiations as having attributes of both particles and waves. It is easy to imagine energy being carried by particles—anyone who has ever been hit by a baseball will verify that this energy transfer is possible. The corresponding behavior in waves is more difficult to visualize, but quantum theory helps in this regard. *Figure 2* shows a diagram of a wave, indicating its two basic characteristics, amplitude

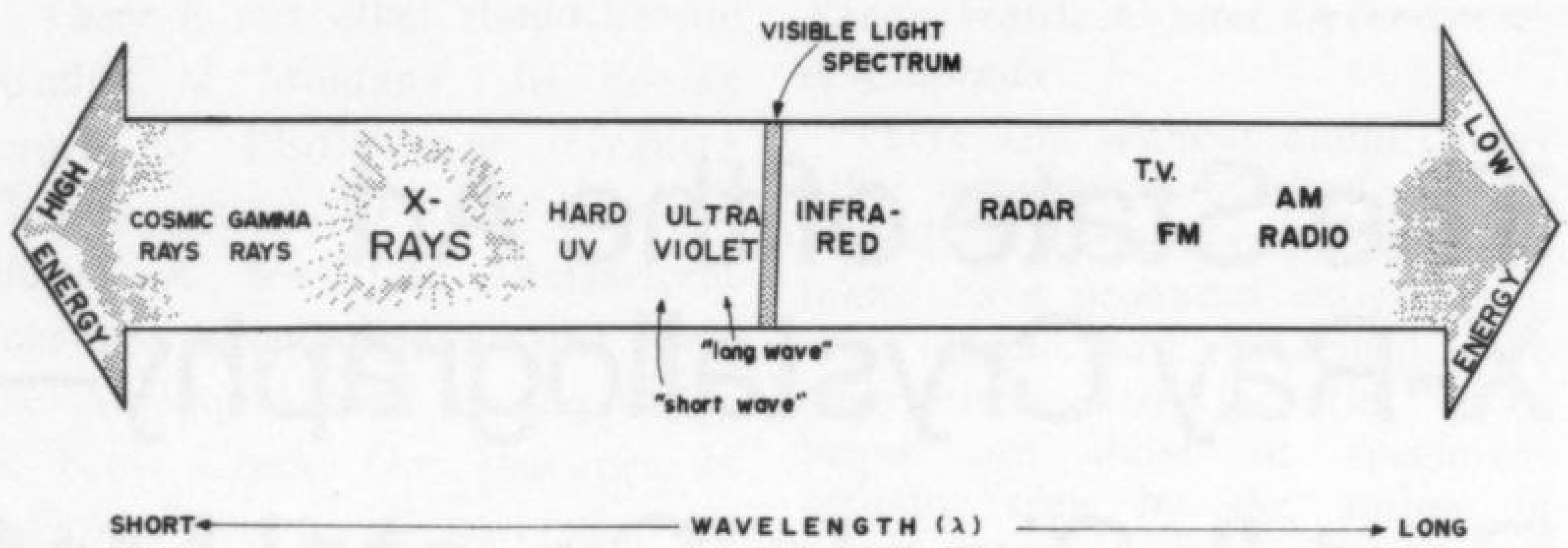


Fig. 1. The electromagnetic spectrum, showing some familiar (named) wavelength regions. Higher energy radiations are associated with short wavelengths, and vice versa. The X-ray region extends approximately from 0.1 to 10 Å.

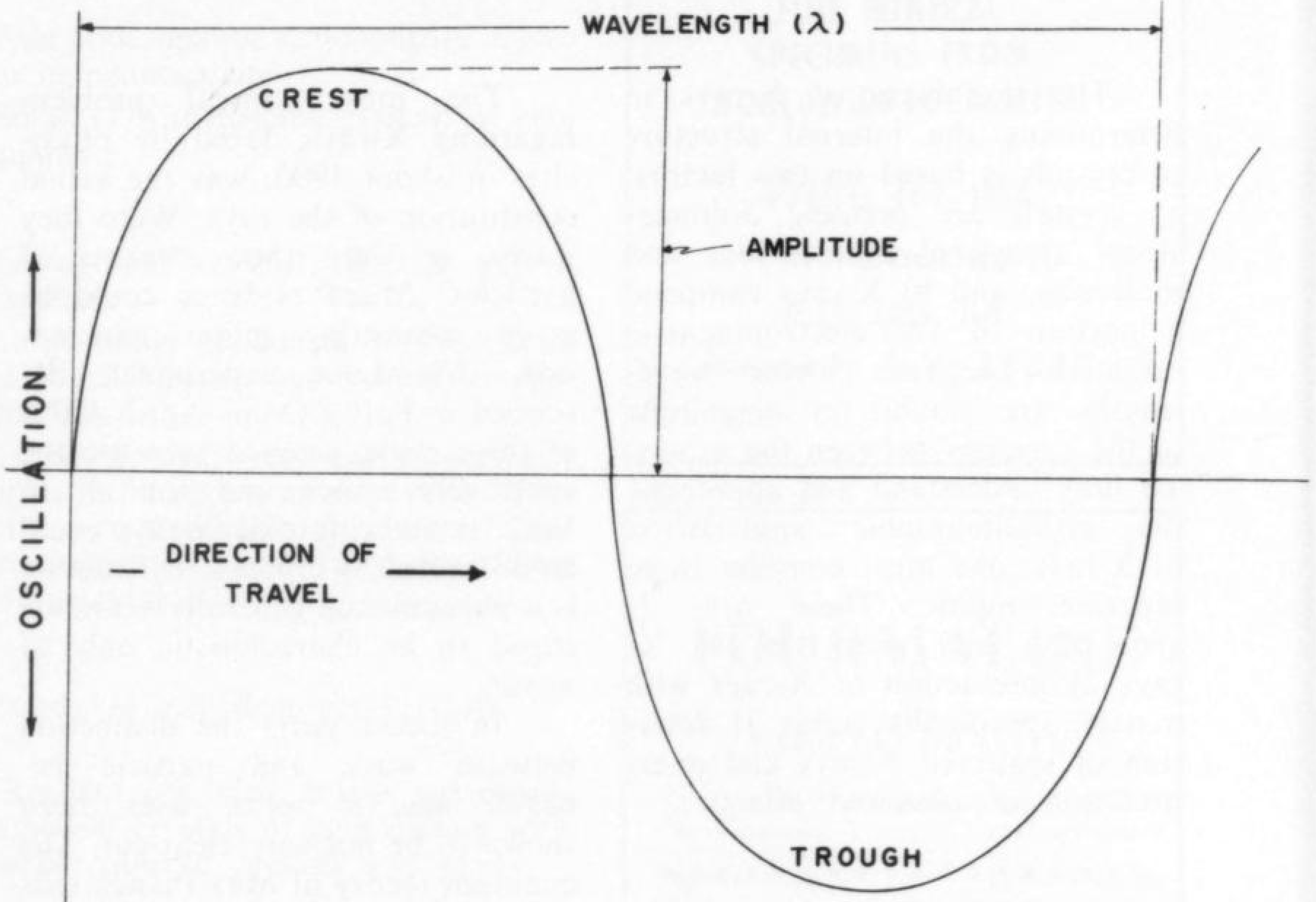


Fig. 2. Sinusoidal wave, indicating characteristic features. Such waves normally vibrate perpendicular to their direction of travel. The amplitude of vibration is a measure of the energy carried by the wave.

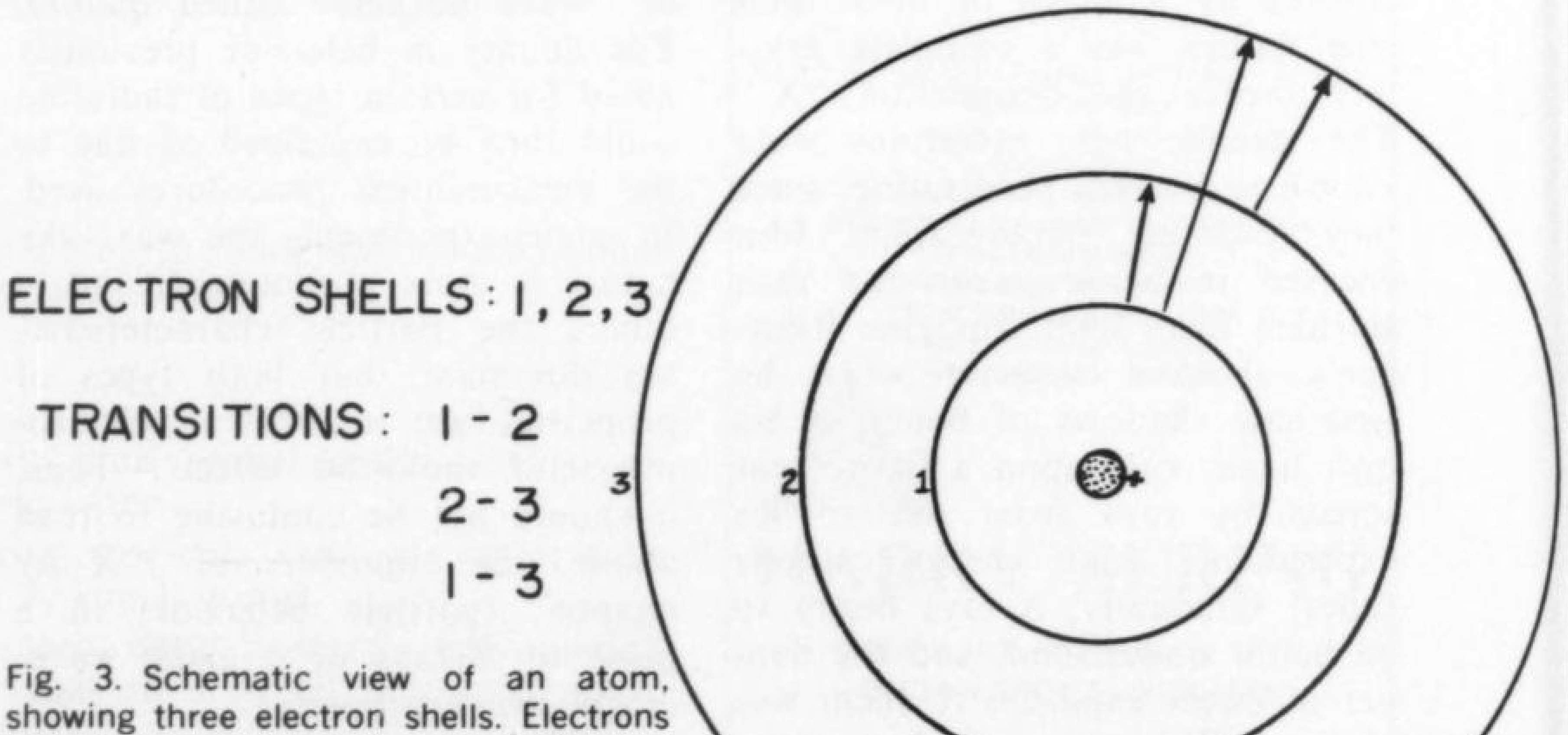


Fig. 3. Schematic view of an atom, showing three electron shells. Electrons can jump only between designated energy levels in atoms (transitions are quantized); each jump has a specific associated energy. Transitions such as 1-3 have higher associated energies than 1-2 or 2-3.

and wavelength. A quantum might be thought of as a wave "packet" that travels through space as a unit. Each displacement of an oscillating wave carries energy; it is therefore obvious that the larger the number of oscillations, the more energy transmitted.

We may imagine a stream of light waves passing a given point, such that we may count the number of waves (measured from crest to crest) that pass in a unit of time. It has been found that all electromagnetic radiations travel at the same speed (the speed of light, 299,792.5 km/sec.); since each wave carries energy, the more waves passing the point in a given time, the more energy transmitted. Obviously more waves of short wavelength can pass the observation point than can those with longer wavelengths, in a unit of time, and thus short wavelengths transmit more energy in unit time. This expresses graphically the relationship between energy and wavelength. *Higher energies are associated with shorter wavelengths,* and with higher frequencies (number of wave oscillations per second).

Electron transitions between widely separated energy levels, or transitions involving electrons close to the nucleus (and therefore very strongly attracted) involve large energies, and are therefore associated with short wavelengths. Visible light effects are produced by stimulation from heat or ultraviolet light sources. These are relatively low-energy excitation sources, and the electron transitions involved are correspondingly unenergetic *(see Fig. 3).*

But the excitation of electrons close to the nucleus requires enormous energies. These can be provided by a stream of particles, such as electrons, that have been accelerated to high velocities. Special electron tubes have been designed for this purpose. Atoms bombarded by such energetic particles undergo inner-electron displacements. These transitions are high-energy jumps, and therefore produce very short wavelength emissions. Such emissions are X-rays.

X-rays can also be produced by X-ray bombardment, a process that will be discussed in detail later.

There exists a spectrum (range of wavelengths) of X-rays, just as in the case of visible light. Colors are distinguised on the basis of wavelength; if our eyes could detect X-rays, we would see a variety of strange, new hues. The X-ray spectrum includes radiations produced by a wide range of electron transitions. Each chemical element produces *characteristic* X-rays, since the electron structure of every element is unique. We may therefore speak of iron X-rays, copper X-rays, and so on. Detection of characteristic X-rays can be used to both identify the presence of an element and to determine the amount present. This type of chemical analysis is called *X-ray fluorescence analysis.* An element can be said to fluoresce in the X-ray region, just as a specimen of willemite, for example, fluoresces in the green portion of the visible spectrum.

Characteristic X-rays can be produced, in an X-ray tube, by impinging a beam of high-energy electrons on a target made of a particular metal. Electrons in the target atoms are excited and emit X-rays in all directions. Early X-ray tubes contained targets that could be removed and changed, so that a variety of X-rays could be produced by a single tube. Modern tubes are sealed, to better preserve the high vacuum needed for their operation, and so a different tube is needed for each wavelength desired. The tubes most commonly used for X-ray diffraction work contain targets of iron, cobalt, copper, chromium, molybdenum, tungsten and silver. The heavier the element (in terms of atomic number) the shorter the wavelength of its characteristic X-rays. Thus, iron, with atomic number 26, produces its most intense X-rays at a wavelength of about 1.9 Å (Å = Ångstrom unit, = one ten-millionth of a millimeter), while molybdenum, number 42, produces 0.7 Å X-rays.

The emission from the filament of an X-ray tube consists of electrons with a wide range of energies. The fluorescent X-rays produced by the target have a correspondingly wide range of wavelengths and are thus termed "white radiation" (by analogy, since white light is a combination of all colors). White radiation is the result of transitions of outer electrons, and

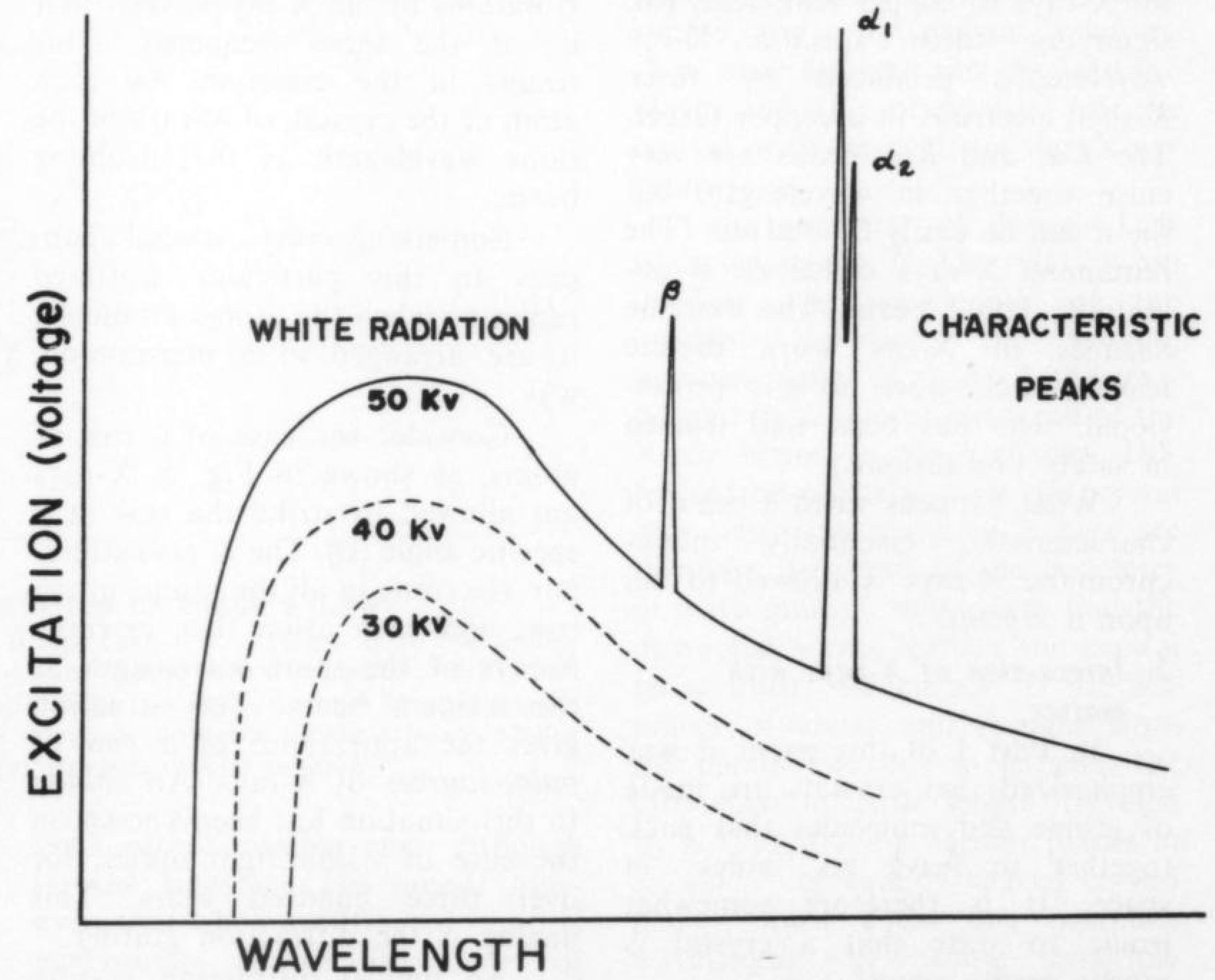


Fig. 4. Spectral emission curve (X-ray region) produced by high-energy bombardment of a target element (such as tungsten). The minimum excitation needed to excite the characteristic lines of an element (here shown to be 50 kilovolts) increases for elements of higher atomic number. The separation of the beta peak from the alpha doublet allows the beta to be easily eliminated by filtration.

is not characteristic of the element producing it. Only when the excitation reaches a minimum level of energy are inner electrons excited and characteristic wavelengths produced. These take the form of "peaks" superimposed on a "hump" of white radiation of much lower intensity *(Fig. 4)*.

X-rays are allowed to leave an X-ray tube through small windows, usually made of beryllium and mica. The desired wavelength is usually a single characteristic peak; but other characteristic peaks, due to transitions of various inner-orbital electrons, are also present in the emission of the tube. These can be selectively removed by means of special filters that absorb unwanted wavelengths. The remaining radiation is essentially monochromatic, that is, of a single wavelength.

Electrons are named according to the shells, or orbits in which they spin about the nucleus. The X-rays produced by ***K***-shell electrons are called ***K*** X-rays, and the same is true for ***L, M*** and other electron shells. Further subdivision depends on the specific electrons involved; typical nomenclature for X-rays is: copper $K\alpha_1$, $K\alpha_2$, $K\beta$, signifying three specific X-ray wavelengths produced by three ***K***-shell electrons in a copper target. The $K\alpha_1$ and $K\alpha_2$ peaks are very close together in wavelength, but the β can be easily filtered out. (The remaining X-rays constitute a potentially lethal beam. The extreme hazards of X-ray work dictate leaving such work to the professional, who has been well trained in safety precautions.)

What happens when a beam of characteristic, essentially monochromatic X-rays is allowed to fall upon a crystal?

2. Interaction of X-rays with matter

In Part I of this paper it was emphasized that crystals are made of atoms and molecules that pack together to leave no "holes" in space. It is therefore somewhat ironic to state that a crystal is mostly empty space!

Atoms consist of electrons spinning about a nucleus. But the sizes of these particles are infinitessimally small compared to the diameter of the atom itself. If electrons were the size of golf balls, an atom (on the same scale) would be miles across; at the center would be a basketball-sized object, representing the nucleus. The spinning electrons form an electronically charged "shell" that acts as a boundary and gives the atom an *effective* size.

Outer electrons of an atom are quite far from the nucleus in the heavier elements; moreover, they are "shielded" from the positive attraction of the nucleus by shells of inner electrons. The outer electrons are therefore weakly held, and are capable of changing position rather easily. The energy of an incident X-ray beam can cause a wide range of electron transitions. The energy released by the electrons on returning to their original orbits thus constitutes a rather large wavelength spectrum of fluorescent X-rays.

Although some of these scattered X-rays have a longer wavelength than the incident X-rays, the incident beam produces yet another effect. It forces some electrons in the atoms of the crystal to oscillate at the same rate as the vibrations of the X-ray waves—that is, at the same frequency. This results in the emission, by each atom of the crystal, of X-rays of the same wavelength as the incoming beam.

Something very special happens to this particular scattered radiation when the atoms producing it are arranged in a non-random way.

Consider the case of a row of atoms, as shown in Fig. 5. X-rays are allowed to strike the row at a specific angle (Θ). The X-rays stimulate electrons in all the atoms in the row, and each atom then ***re-emits*** X-rays of the same wavelength as the incident beam. This situation gives the appearance of a row of *point-sources* of X-rays. An analog to this situation has been known, in the case of visible light optics, for over three hundred years. This analog is the diffraction grating.

An optical diffraction grating is usually made by scratching a number of closely-spaced lines onto a transparent material, such as glass. Modern techniques are capable of ruling as many as 40,000 lines per inch, thus making the spaces between the lines narrower than the length of visible light waves. Light passing through such a grating emerges in a restricted way, just as if each tiny opening were a new *source* of light waves *(Fig. 5)*. The waves emerging from adjacent point-sources interfere with one another, canceling out in some directions and reinforcing in others. The result at a distance from the grating is a series of light and dark regions, known as *interference fringes*. The process that forms them is called *diffraction*.

A row of atoms is periodic in much the same way as uniformly-spaced lines and spaces on an optical grating. The atoms reradiate incident X-rays as if they were a row of point-sources of waves, also analogous to the optical experiment.

For the most part this scattered radiation is random and therefore diffuse. But when the incident X-ray beam makes a certain angle with the row of atoms, the scattered radiation adds up along specific directions and can be detected as diffracted beams, similar to the bright fringes of an interference pattern. The diffraction of X-rays is thus actually a *scattering* process, and is highly angle-dependent.

Max von Laue showed in a series of papers (that led to the Nobel Prize in Physics) that the size of a diffracted beam depends on the number of atoms in the row, and that diffracted beams are created only when the atom row makes specific angles with the incident X-ray beam. The mathematical expressions of these two discoveries are embodied in the so-called *interference function* and in the *Laue equations*. Of course, a crystal consists of more than a single row of atoms. In fact, a crystal is built of atoms that are spaced periodically in three dimensions, rather than one. The restrictions for diffraction that apply to a row of atoms also apply to a lattice array of atoms, but they are rather complex for three dimensions. With astonishing insight, William L. Bragg realized that the complex Laue equations could be greatly simplified.

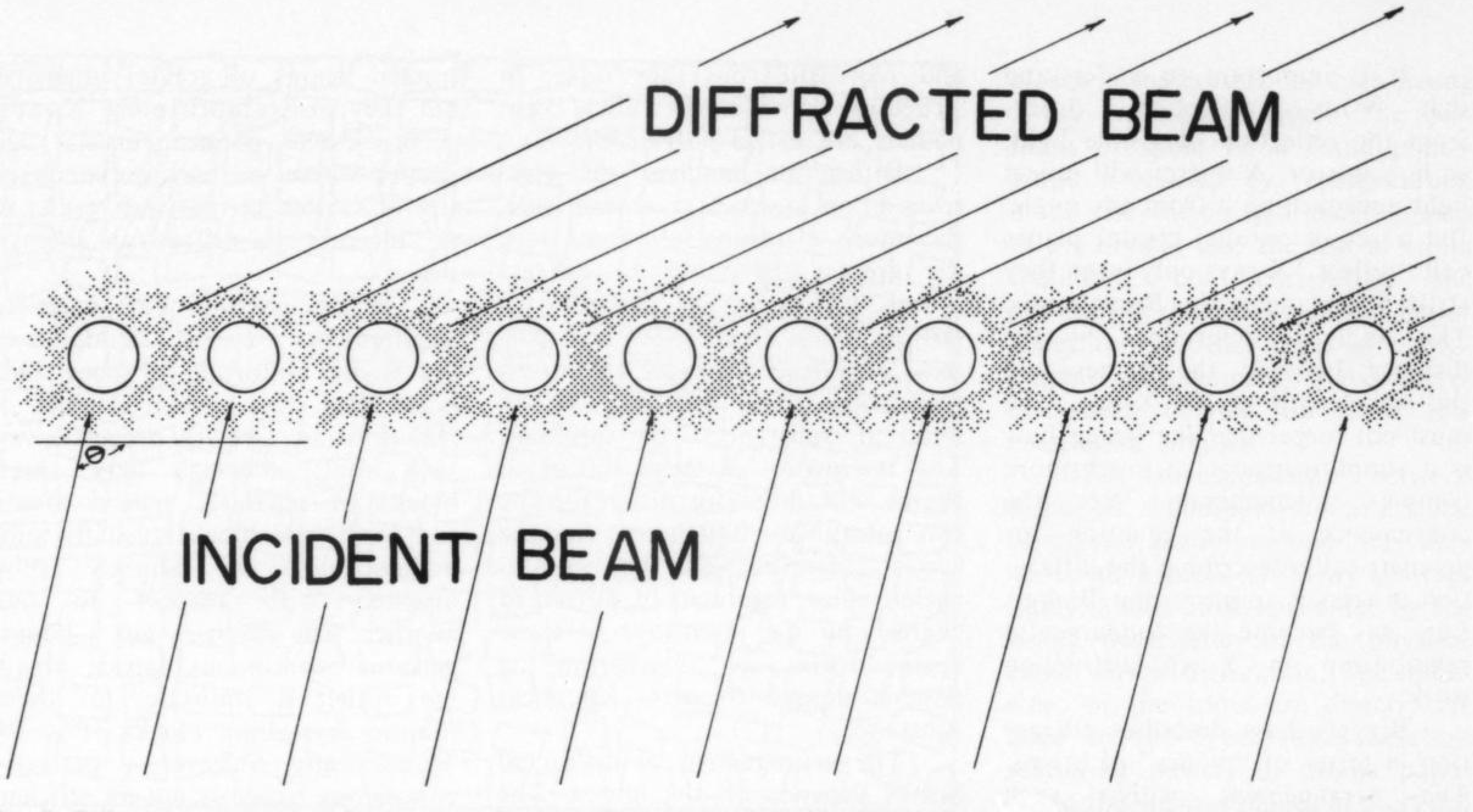
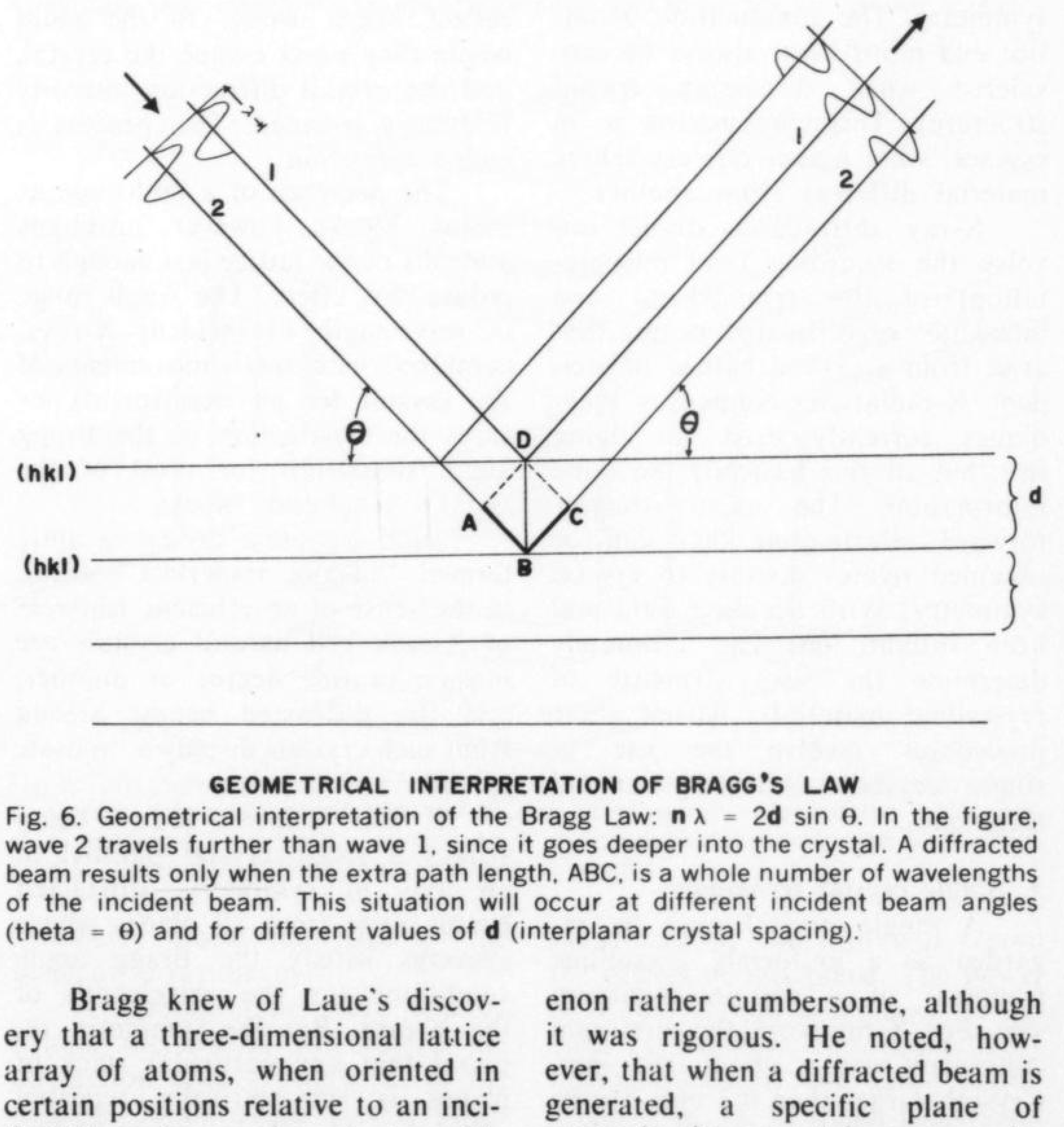


Fig. 5. Diffraction (scattering) from a row of atoms. The atoms all scatter X-rays (from incident beam) in all directions; most of the scattered radiation is fluorescent (non-coherent), except when theta is a Bragg angle. The atoms then re-emit X-rays of the same wavelength as the incident beam, scattering is termed coherent, and a diffracted beam results.



GEOMETRICAL INTERPRETATION OF BRAGG'S LAW

Fig. 6. Geometrical interpretation of the Bragg Law: $\mathbf{n}\lambda = 2\mathbf{d}\sin\theta$. In the figure, wave 2 travels further than wave 1, since it goes deeper into the crystal. A diffracted beam results only when the extra path length, ABC, is a whole number of wavelengths of the incident beam. This situation will occur at different incident beam angles (theta = θ) and for different values of **d** (interplanar crystal spacing).

Bragg knew of Laue's discovery that a three-dimensional lattice array of atoms, when oriented in certain positions relative to an incident X-ray beam, gives rise to a diffracted beam within the crystal. Bragg found the mathematical explanation offered for this phenomenon rather cumbersome, although it was rigorous. He noted, however, that when a diffracted beam is generated, a specific plane of atoms in the crystal happens to be oriented in a special way: the diffracted beam *seems* to arise *as if* it were a *reflection*, of the incident beam, off of this plane.

The complex geometry of diffraction could thus be conceptually simplified, by merely treating diffracted beams as reflections. It was easy to show that rather simple and very elegant relationships exist between this "reflection" plane and the orientation of the crystal with respect to the X-ray beam.

The geometry of Bragg's Law is shown in *Fig. 6*. The relationship involves the wavelength of the incident radiation, the spacing between planes of atoms in the crystal and the angle of incidence of the X-ray beam on these planes. Diffracted beams arise from the crystal only when the scattered X-rays are *in phase*. In terms of the geometry of wave motion, this means that the diffracted waves leaving the crystal plane must "match up" in the distances of crests and troughs from the plane. For this to happen, the difference in path length traveled by X-rays striking various planes in a "stack" of equally spaced crystal planes, must equal one complete wavelength or some multiple thereof. This, in essence, is the message of the Bragg equation as well as the more complex Laue conditions.

It is important to understand that X-ray "reflection" differs from the reflection of visible light, as in a mirror. A mirror will reflect light approaching it from any angle. But a set of parallel crystal planes will "reflect" X-rays only when they strike the plane at the ***Bragg angle***. This angle is determined by the distance between the planes and the wavelength of the X-rays. We must not forget that the Bragg Law is a simplification of a much more complex phenomenon. Yet the convenience of the equation for geometrically describing the diffraction process is so great that Bragg's Law has become the fundamental relationship in X-ray diffraction work.

Bragg's Law describes diffraction in terms of "planes" of atoms. The arrangement within such planes, as well as regularity in interplanar spacing, is due to translational symmetry—the symmetry created by lattice displacements. The physical conditions that govern the positions of diffracted X-ray beams are thus a function only of lattice symmetry.

This has some rather surprising consequences. Any two crystals with lattices of the same size and type will produce identical ***arrangements*** of diffracted beams. That is, identical lattices will give rise to diffracted beams at the same Bragg angles.

This might at first seem confusing. How can two crystalline substances have identical lattices? Yet this is not at all surprising, considering the very large number of chemical compounds that exists and the very limited number of lattice types (namely, 14). Duplication should occur often, and even exact equivalence in lattice size can be expected. How, then, can one differentiate between substances with identical lattices? For this we must note that ***no*** two distinct substances have both identical lattices AND atomic arrangement and constitution.

Every chemical compound has a unique combination of lattice and motif symmetry that, taken together with the composition, unambiguously identifies it. Two or more compounds may have identical composition, as in the case of pyrite and marcasite, but they differ in structural arrangement. Such compounds are called ***polymorphs***.

Diffraction involves the electrons in an atom; as a general rule, the more electrons an atom has, the greater its power to diffract X-rays. Thus, even though two lattices may create identical patterns of diffracted beams, the atoms populating these lattices will, in different substances, be different. The ***intensities*** of these diffracted beams will therefore differ for the two substances, and herein lies the key to identification. The combination of arrangement of diffracted beams ***and*** the intensities of these beams forms a "fingerprint," a pattern unique to every chemical substance.

The arrangement of diffracted beams depends on the lattice. The intensities of the beams are due to the scattering power of atoms and their positions with respect to the lattice, as determined by motif symmetry. The combination of lattice ***and*** motif must always be considered when discussing crystal structures. This combination is, in essence, what makes one crystalline material different from another.

X-ray diffraction studies involve the recording (and interpretation) of the arrangement and intensities of diffracted beams that arise from a crystal bathed in incident X-radiation. Numerous techniques currently exist for doing this, but all give basically the same information. The most straightforward information that can be obtained relates directly to crystal symmetry. With accurate data and keen insight, one can ultimately determine the very structure of crystalline materials. All of these procedures involve the use of single crystals and single-crystal techniques.

3. Single crystal techniques

A single crystal may be regarded as a uniformly crystalline fragment of a certain minimum size. For X-ray work the minimum convenient size is about 0.05 mm. Crystals larger than 0.3 mm can be used, but their larger size often becomes a liability rather than an asset. Large crystals do indeed scatter more X-rays and give diffracted beams of greater intensity, but they also absorb more X-rays. A break-even point in crystal size occurs where increasing the quantity of scattering material results in no increase in diffraction intensities.

As discussed in Part I lattice requirements forbid symmetries that do not uniformly fill space. This is an ideal state seldom attained in real crystals. Growth processes are such that, although very small blocks of regularly spaced atoms can form, the blocks (usually submicroscopic) are slightly misoriented with respect to one another. The result is not a homogeneous, continuous lattice array, but rather a "mosaic" of these minute crystalline blocks *(Fig. 7)*. Theoretically, however, a perfectly continuous lattice is not an efficient X-ray scatterer. X-rays are diffracted by ***both*** sides of crystal planes. Diffracted beams arising deep within a perfect crystal thus reflect black inside, to the point where they never escape the crystal, and the overall diffraction intensity is greatly lessened. This process is called *extinction*.

The presence of a multitude of mosaic blocks, however, misaligns portions of the lattice just enough to reduce this effect. The small range in wavelength of incident X-rays, combined with small movements of the crystal (in an experiment) insures the satisfaction of the Bragg angle conditions for most of the slightly misaligned blocks.

Such a mosaic crystal is aptly termed "ideally imperfect"—ideal, in the sense of an efficient scatterer of X-rays. All natural crystals are mosaic to one degree or another, and the diffracted beams arising from such crystals display a "mosaic spread."

If an incident X-ray beam strikes a single crystal parallel to an axis of symmetry, diffracted beams arise from all planes whose spacings satisfy the Bragg angle conditions for the wavelength of the X-rays. But the symmetry requires that any particular stack of planes is symmetrically repeated about the axis. This is shown in *Fig. 8*, and indicates that the diffracted beams arising from the crystal must form a pattern that reveals the

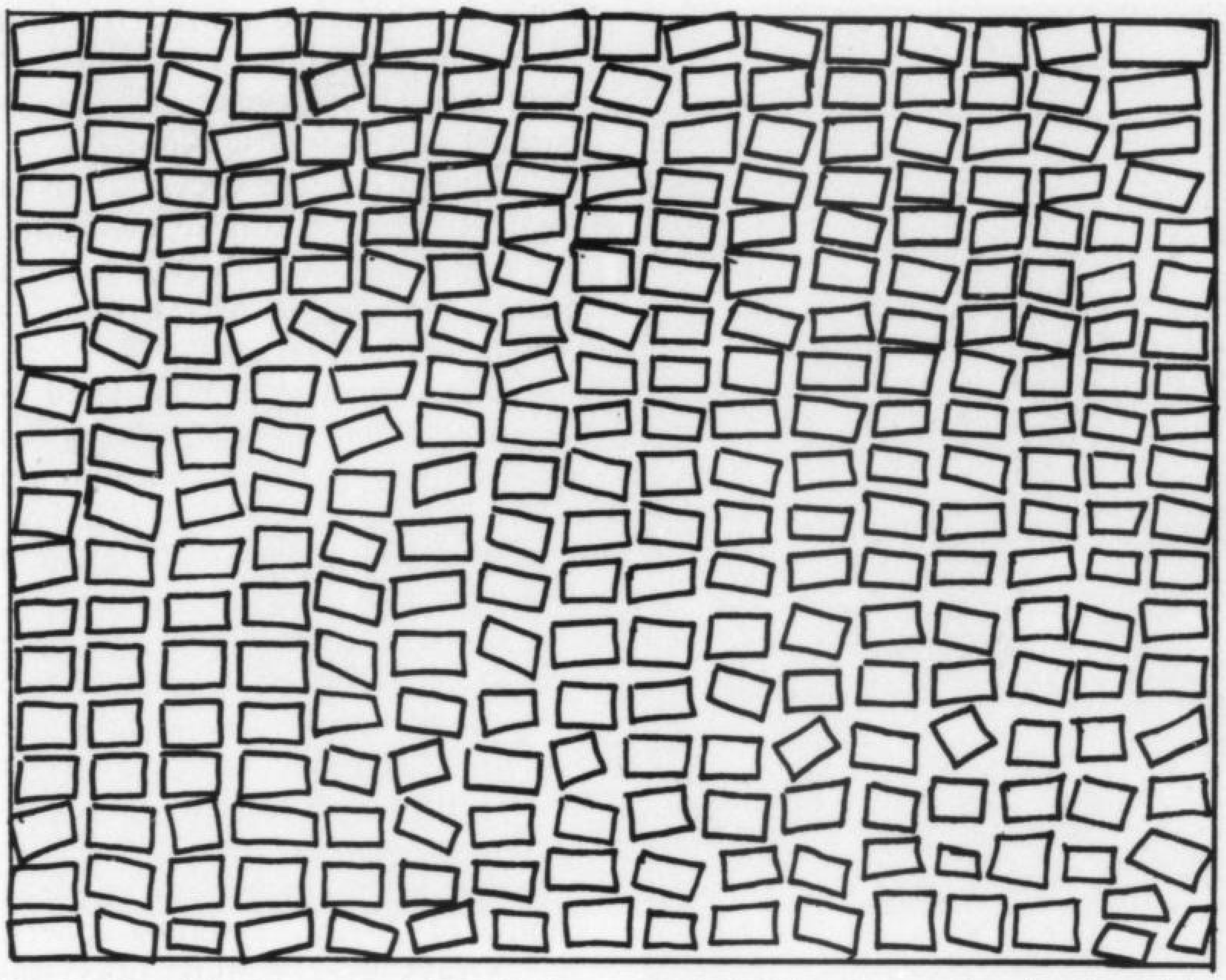


Fig. 7. Mosaicity in a crystal. This is the normal situation for most natural crystals. The slight misalignment of the "blocks" in the crystal (which are as small as several dozen molecular units in size) allows diffraction to occur over a slight range of Bragg angles for each particular value of **d** and angle theta. Instead of a sharp diffracted X-ray peak, one observes a rounded, wide peak, said to be due to "mosaic spread."

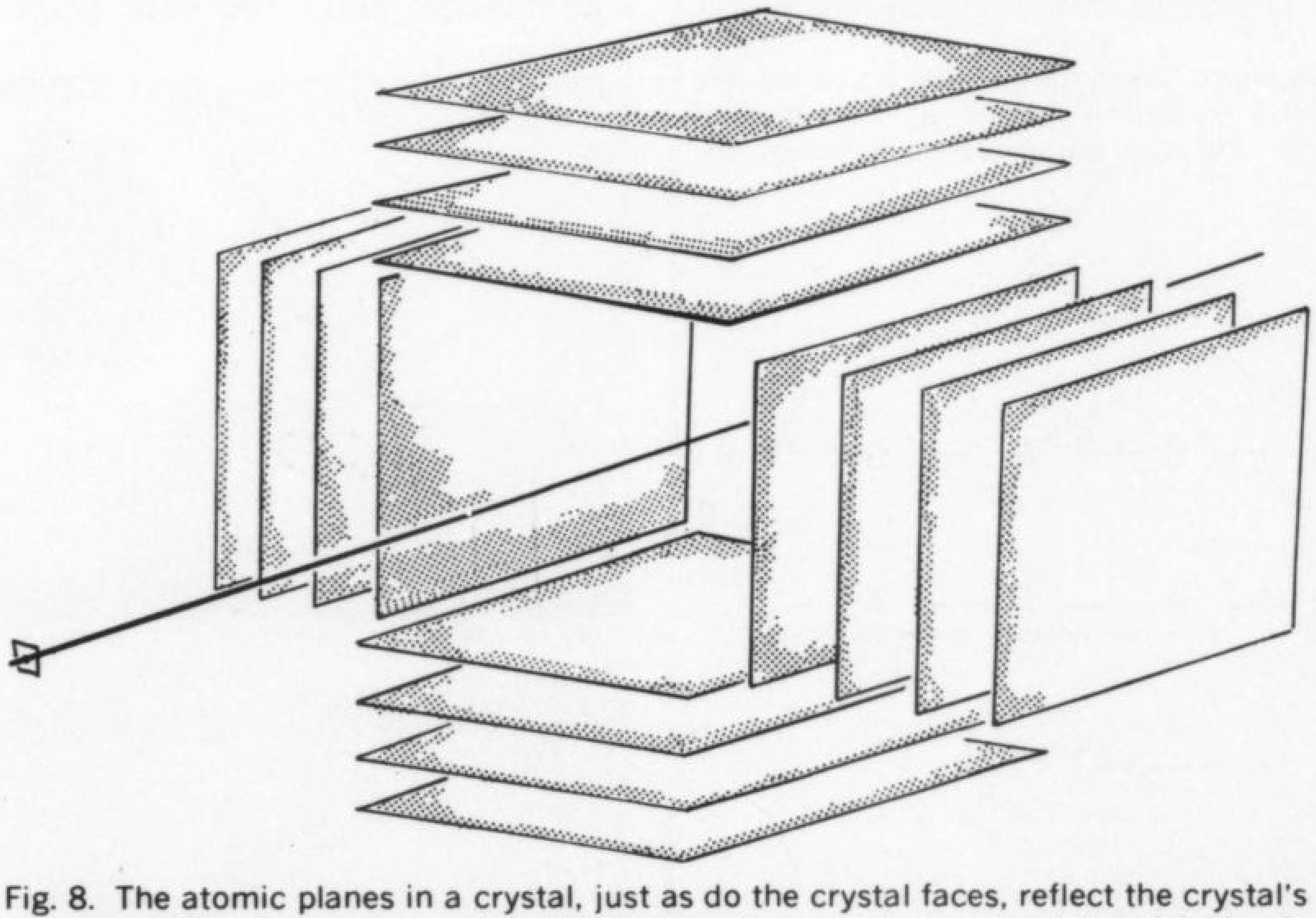


Fig. 8. The atomic planes in a crystal, just as do the crystal faces, reflect the crystal's symmetry. The figure shows the distribution of some planes about the 4-fold axis of a tetragonal or isometric crystal. An X-ray beam passing down this axis would produce diffraction effects showing 4-fold symmetry.

symmetry along the path of the incident X-ray beam.

A photographic plate located behind the crystal will record the diffraction effects produced. If the incident X-ray beam travels down an axis of symmetry, the diffracted beams will create on the film a pattern with this symmetry. If the incident beam is parallel to a plane of symmetry, the film will record the effects of this plane. The power of single crystal techniques to record symmetry is spectacularly demonstrated by the Laue photograph *(Fig. 9)*, in which the crystal remains stationary throughout the exposure. Every spot on such a photograph represents diffraction from a particular stack of atomic planes in the crystal, for each strong X-ray wavelength used. The plethora of spots on a Laue photograph is caused by representation of all the variously-oriented planes in the crystal and the use of white radiation; but correlating the planes with the spots can be a major undertaking. Other types of photographic arrangements have therefore been devised to make this correlation simpler.

The correspondence between a spot on a photograph and a stack of crystal planes is one that pervades all aspects of X-ray photography, and is easily explained by the Bragg description of the physical conditions of diffraction. The intensities of the spots are directly related to the types (and therefore scattering power) of atoms populating the various planes of a crystal and the density of the population. *Fig. 10* shows that different planes within a crystal incorporate atoms in different proportions.

The spot arrangement indicates the basic mathematical architecture of a crystal, that is, its lattice; spot intensities reveal the internal atomic arrangements characteristic of the motif. The intensities and positions of diffracted beams contain the information needed to deduce the atomic distribution that produced the diffraction pattern. This task is perhaps one of the least trivial in modern science. To accomplish it, very detailed X-ray information is required. During the past fifty years increasingly sophisticated devices and techniques have been developed to obtain this information.

The Laue technique was one of the earliest to be developed. It is easy to manage, experimentally, but the information it provides requires a great deal of interpretation. In effect, as might be surmised from the description of a Laue photograph presented earlier, too much information is present—many diffracting planes of the lattice are projected onto the single plane of the photograph. If the planes could be sorted out, interpretation of the diffraction information would be much simpler.

The ***Weissenberg method*** was devised as a step in this direction. A single crystal is rotated in a filtered, monochromatized (to Kα) X-ray beam while a cylinder of film, surrounding the crystal, moves parallel to the rotation axis.

This procedure records only a small number of diffracted beams, and in a slightly distorted fashion due to the motion of the film, as shown in *Fig. 11*.

This distortion is eliminated in the ***precession method*** by means of an elaborate and complex motion if the camera itself *(Fig. 12)*. Precession photographs *(Fig. 13)* clearly show crystal symmetry, and are also useful in determining the space group of a crystal. The diffraction spots can usually be readily "indexed"—correlated with crystal planes. Simplicity of interpretation makes the precession method, for routine work, a first choice of X-ray crystallographers.

X-rays reveal features of crystal structure impossible to detect by other means. It has already been mentioned that real crystals may contain glide planes and screw axes in addition to mirror planes and rotation axes. The glide plane

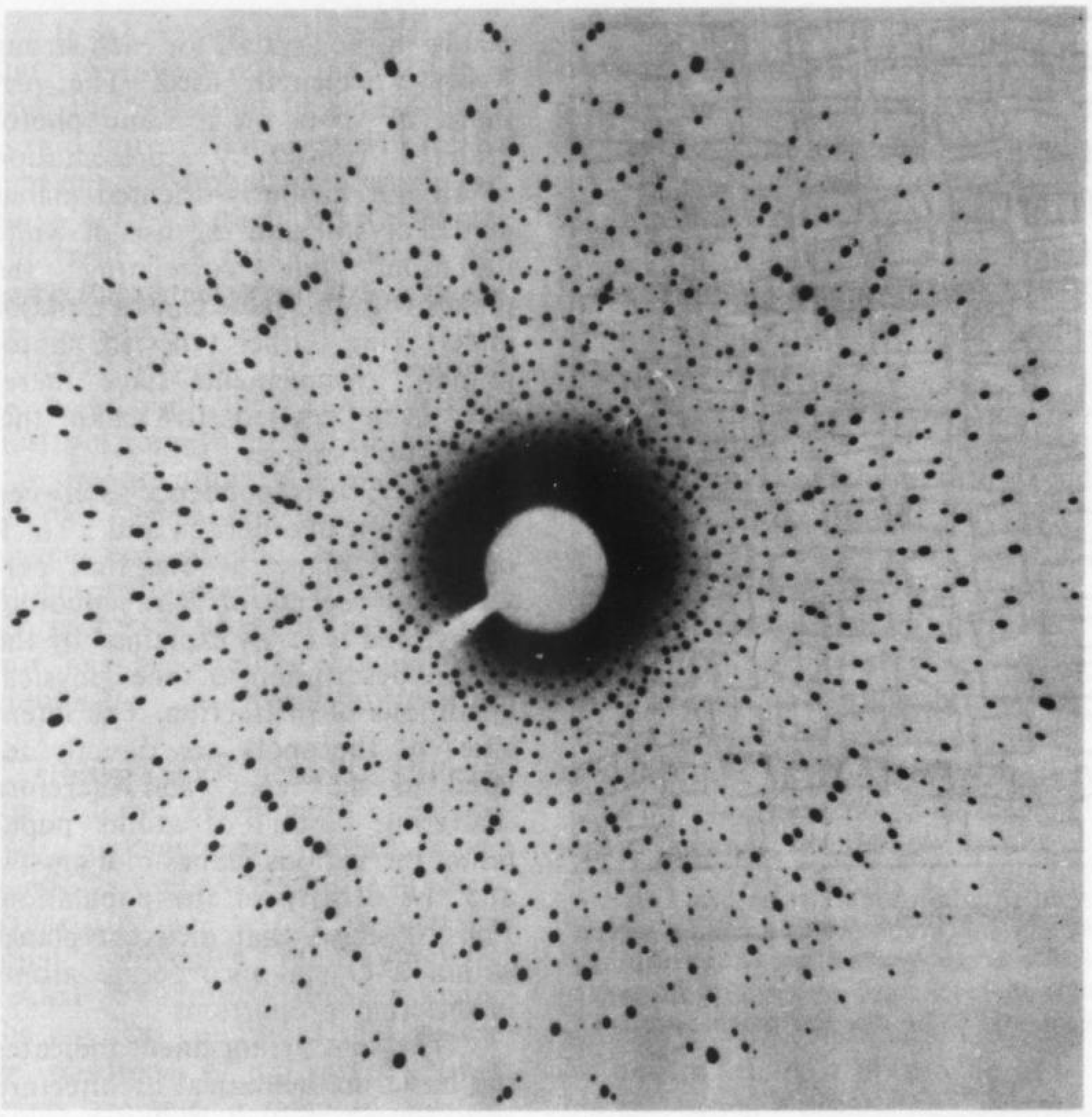


Fig. 9. Laue photograph of idocrase (tetragonal), taken down the **c**-axis of the crystal. Many diffracting planes, and "white" radiation (range of wavelengths) produce large numbers of diffracted beams. Yet the pattern clearly shows the 4-fold symmetry of the mineral's structure.

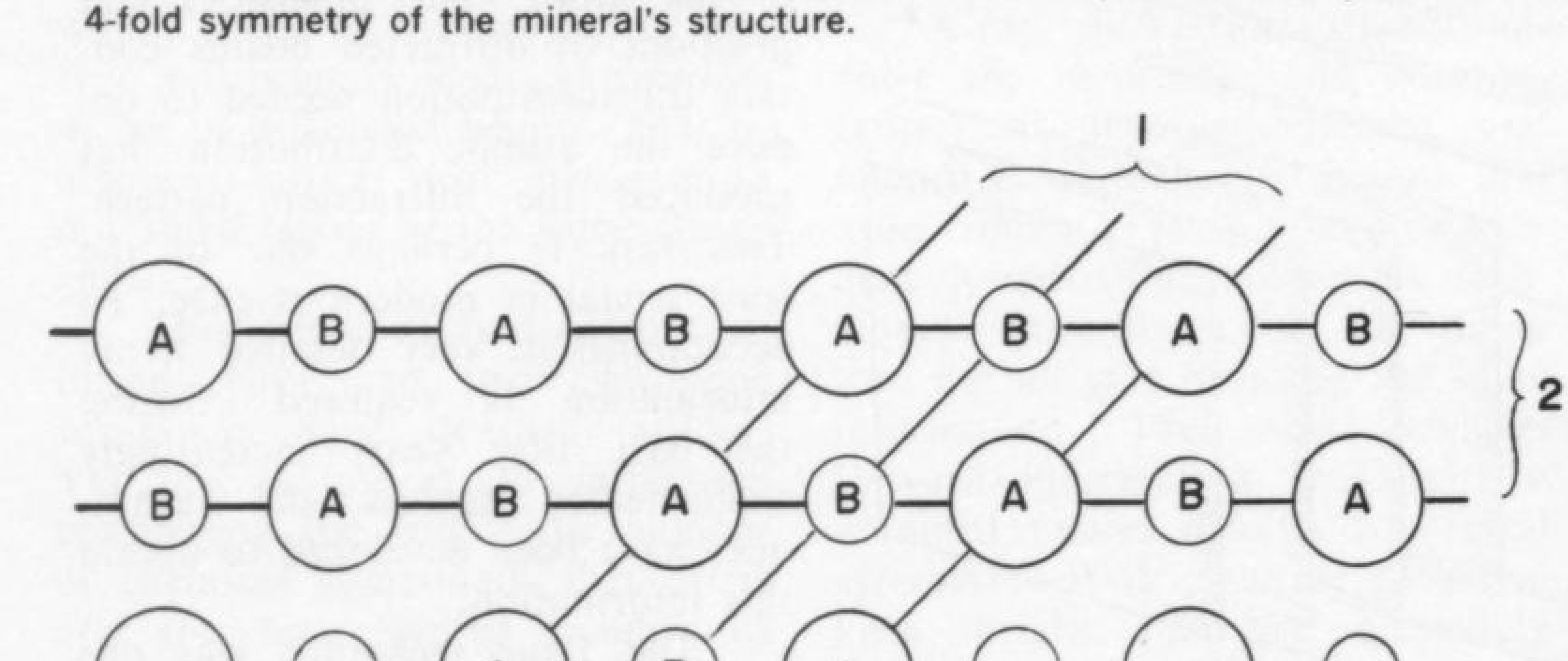


Fig. 10. Schematic view of a crystal structure, showing several sets of atomic planes. It is evident that the planes labeled 1 have a different atomic population and different atom density than the planes labeled 2. Planes 1 are monatomic (only atoms A or B) while those marked 2 alternate A-B-A-B-A.

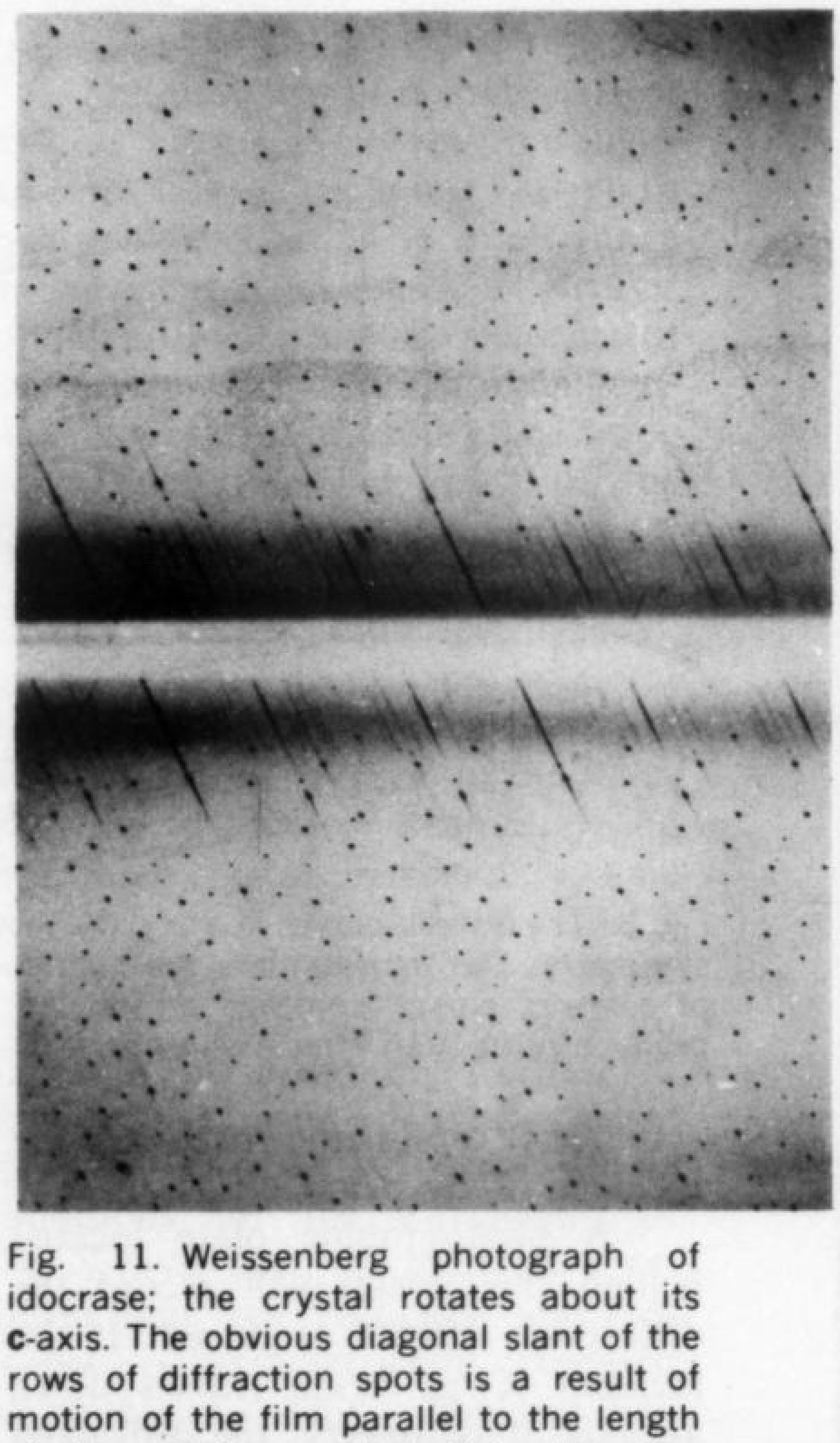


Fig. 11. Weissenberg photograph of idocrase; the crystal rotates about its **c**-axis. The obvious diagonal slant of the rows of diffraction spots is a result of motion of the film parallel to the length of the rotating crystal. This distortion is a chief disadvantage of the Weissenberg technique. (Film taken with Cu radiation; O-level).

Fig. 12. The author is shown aligning a crystal on a Buerger Precession camera. The rather complex gear mechanisms on this camera eliminate the distortions of the Weissenberg technique, and give direct, angle-true views of crystal symmetry.

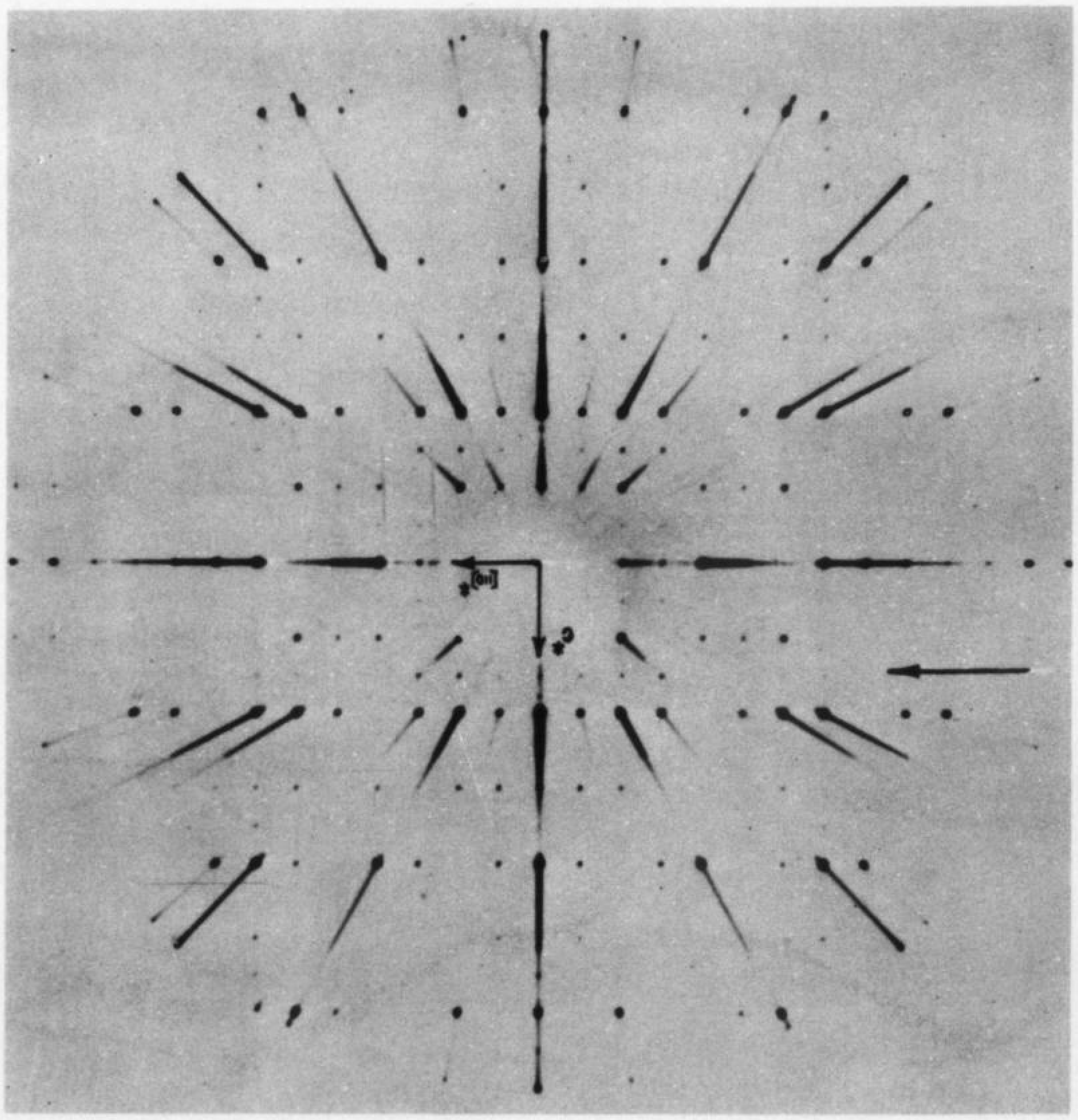


Fig. 13. Precession photograph, taken down [110] of idocrase. This orientation of a tetragonal mineral should yield a photograph with **2mm** plane symmetry—a 2-fold axis normal to the plane of the photo, with 2 mirror symmetry planes at right angles to one another intersecting in the center. Such symmetry is visible in the photograph.

is a feature that involves displacement of atoms through a reflection, followed by a translation that is some simple fraction (½, ¼) of a fundamental, or unit translation of the lattice. But the resulting atomic arrangement is still periodic in three dimensions, and the small displacement is undetectable on a macroscopic scale. A crystal containing a glide plane instead of a mirror plane appears, macroscopically, to exhibit a mirror plane.

X-rays are sensitive to the precise locations of planes of atoms. Consider the arrangement shown in *Fig. 14,* comparing a mirror-plane array with an equivalent glide-plane arrangement. In the case of the mirror plane, X-rays indicate a particular spacing between planes (rows, in cross section) of atoms. In a glide array, the additional translation component of the glide has effectively created a new *spacing* in the crystal.

This small atomic shift would be microscopically invisible. On an X-ray photograph, however, since diffracted beams indicate atomic spacings, the effect of a glide plane is to eliminate entire rows of diffraction spots. ***X-rays can thus be used to determine the space group of a crystal (of which there are 230) whereas morphological studies can only disclose the crystal class, or point group (of which there are 32).***

The space group neatly summarizes detailed atomic information about crystals. The crystal class of an orthorhombic substance might, as an example, be ***mmm*** (the "short form" for 2/*m* 2/*m* 2/*m*) meaning that each of the major axes of the crystal is a 2-fold rotation axis perpendicular to a mirror plane of symmetry. The space group of such a crystal might then be ***Pmmm,*** indicating that the lattice type is *primitive* (contains one lattice point at each of the eight corners of the unit cell, with no lattice points inside the cell or on its faces), and that the atomic arrangement contains mirror planes, as exhibited by crystal morphology. But the space group might, on the other hand, be $Pn2_1a$. In this example mirror planes are, for the atomic structure, replaced by glide planes (***n*** and *a*), and one crystal axis is a 2-fold screw. An ***n***-glide has a *diagonal* transla-

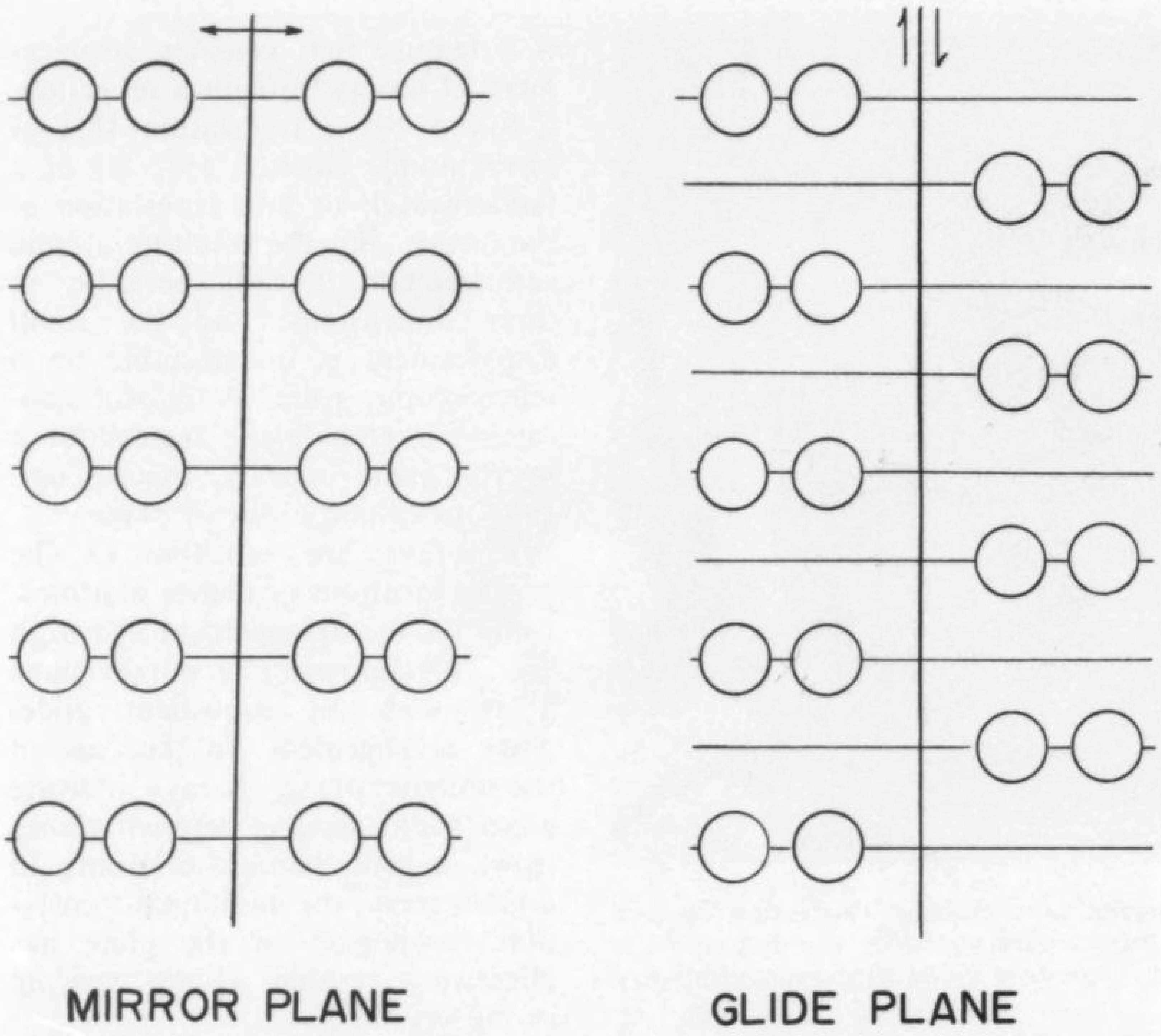


Fig. 14. Comparison of effects of glide plane and mirror plane. The glide operation introduces a "shear" into the succession of crystal planes, effectively producing a new spacing in the crystal half that in the mirror arrangement. The effect of this on X-ray photographs is the elimination of whole rows of diffraction spots, and the glide plane can thus be detected.

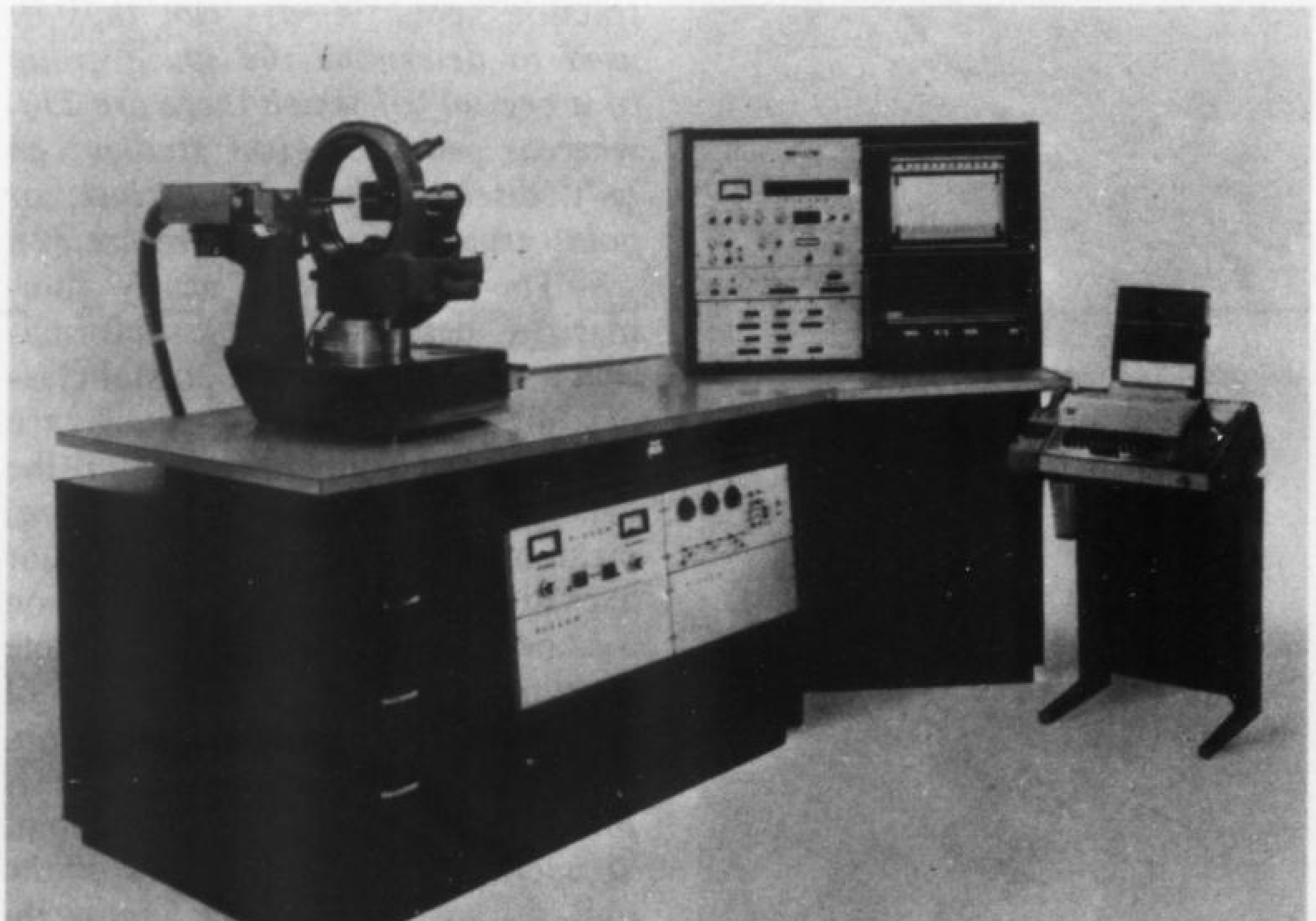


Fig. 15. Single crystal X-ray diffractometer (courtesy of Picker Nuclear Corp.). The instrument shown consists of a highly stabilized X-ray generator (lower part), a crystal-holding device that can position the crystal in virtually any orientation with respect to the X-ray beam (small donut-shaped mechanism), a teletype (on floor) to record the output data and communicate with the small computer (sitting on top of generator) that runs the unit automatically. Once started, this machine will automatically collect all the data needed to solve a crystal structure in a continuous operation that may last many weeks.

tion in the unit cell, while an *a*-glide has a translation component parallel to the *a* axis. The 2_1 screw refers to the *b* axis of the crystal.

It is important to realize that ***the symmetry of the external form of a crystal containing glide planes and screw axes will be that of the point group (crystal class) that would be compatible with the space group, with the glides and screws replaced by mirrors and rotors.***

$Pn2_1a$ would possess *m2m* point symmetry, indicating that this crystal belongs to the hemihedral class. The space group notation is an ultra-compact shorthand nomenclature that conveys to the crystallographer, in a few symbols, all needed information about the symmetry of a crystal structure.

But knowledge of the lattice type and the symmetry of the motif are not the same as knowledge of the crystal *structure*—the exact location of all the atoms. The foregoing discussion may have created the impression that solving this problem is a straightforward and uncomplicated task. In some cases, where the chemistry is simple and the lattice highly specialized, structure determination may indeed be simple. But in most cases additional, complicating factors have to be faced.

As noted previously, every atom has a particular "scattering power," depending on its electronic structure. But the amount of radiation scattered by an atom also depends on the relative angular positions of the incoming and scattered beams. In the case of a crystal structure, all the atoms in the crystal *scatter* X-rays for every position of the crystal, but most of this scattered radiation "destroys" itself (a process called *destructive interference)* and never gets out of the crystal. Only in the directions specified by the Bragg equation does any intensity build up and these constitute diffracted beams.

The diffracted beam therefore carries information about the positions and types of atoms that created it. Each type of atom contributes scattered radiation to a diffracted beam; the relative positions of the different atom types cause some of these contributions to be slightly out of phase with each other. One can therefore think of "positive and negative" contributions to the diffracted beam, and the overall sign of the beam can be considered positive or negative, depending on the magnitudes of the individual atomic contributions.

Although the signs are present in each diffracted beam arising in the crystal, when the beams are actually detected (at some distance from the crystal) it turns out that the signs have disappeared! The magnitude of the diffracted beam at the point of generation in the crystal is called its ***amplitude,*** and all the amplitudes have signs. But the various components of a diffracted beam, in traveling some distance from the point of origin, combine in a somewhat unexpected way. (The exact physical reasons for this are too technical for inclusion here). The amplitudes become ***squared,*** and the detector measures a quantity called the ***intensity,*** rather than the amplitude. This amplitude-squaring process is a general effect for all magnitudes derived from electromagnetic radiations. Simple algebra tells us that the square of either a negative or a positive number is positive. Thus, all the measured intensities have positive signs. Taking the square root of an intensity value gives an amplitude, but one cannot tell if the amplitude was originally positive or negative—the sign is irretrievably lost in the squaring process.

The sign of an amplitude, sometimes called the ***phase*** of the diffracted beam, carries atomic positional information, and its loss in diffraction experiments is the so-called "phase problem of X-ray crystallography." If not for the phase problem, crystal structure determination would be a rather trivial chore, and a routine procedure for computers.

It may now appear that the determination of crystal structures must be impossible to achieve through experimental means. Nonetheless, although it requires the most precise possible experimental data, as well as large computers and keen insight on the part of the crystallographer, structure determination is a routine, albeit challenging procedure today. The gathering of data for this work involves measuring both the positions and intensities of large numbers of diffracted beams. This information is difficult to obtain from photographs, although it has been done for many years. To streamline the procedure, the single crystal diffractometer ***(Figure 15)*** was devised.

The diffractometer is a highly sophisticated tool. It is capable of placing an X-ray detector (such as a Geiger counter) in position to record all possible diffracted beams arising from a crystal (within certain mechanical restrictions). The angular positions of the beams can thus be precisely determined and their intensities measured.

Once diffraction data for a crystal have been obtained, all that remains is to deduce the atomic arrangement that produced them. As mentioned above, this would be a simple job if not for the loss of the phase signs. Mathematical methods have actually been developed in the past few years for determining the signs directly, on the basis of the probability of their being positive or negative for specific classes of diffracted beams.

But most of the structures determined in the past 50 years have been solved with other methods, all of them involving trial models.

A hypothetical model of the structure in question is first invented, containing all the atoms believed to be present and in their suggested positions. To devise such a model in the first place usually requires the "educated guesses" that derive from a good basic knowledge of chemistry. Some very complex calculations are then performed to determine the positions and intensities of diffracted beams that would be expected from this model. These values are compared with data obtained from an actual crystal of the material being studied. If the data agree, then the model was correct and the structure is considered solved. If the match is poor, the model is changed and the calculations again performed. This iterative process continues until the overall discrepancy (usually called the ***R***-factor, or ***R***-value) between data from the crystal and the model falls below 5-10%.

Many structures examined between 1920 and 1935 were considered solved when ***R*** was only about 25-35%. Many times the data were simply compared in a general way, with the match considered "excellent" or "good" or "fair." Such ***R***-values actually indicate that the general aspects of the structure have been found, but changes in atom positional coordinates (and perhaps even some changes in the number and/or types of atoms present) are still required. The process of narrowing down these parameters by iterative data-matching is called ***structure refinement.*** Values of ***R*** as low as 2-3% are currently obtainable.

Although it may seem surprising, structural information is often necessary to be able to write the correct formula for a crystalline material. In fact, the unit cell size, density and formula are all intimately related. Consider, for example, a hypothetical silicate crystal containing iron, magnesium, silicon and oxygen atoms. The space group of the crystal can be determined, and it is found to belong to the orthorhombic system. In addition, the symmetry properties of the crystal indicate that the ***general position multiplicity*** is 8. This means that an atom placed in a random position in the structure would appear (just as in the case of a crystal face acted upon by point group symmetry elements) eight times in the unit cell. If we assume that one of the oxygens is on such a general position in the structure, it automatically follows that there must be seven more oxygens, on symmetry-related sites, in a single unit cell. The symmetry operations relating these atoms are dictated by the space group.

Consider, as another example, the case of an iron oxide whose cell formula has been determined, by chemical analysis, to be Fe_8O_{12}. It follows that oxygens in this structure are ***not*** on positions whose multiplicities are multiples of eight. However, some positions in the cell may be ***sub***multiples of eight (such as 4 or 2); adding the oxygen populations of all these sites gives the 12 oxygen atoms indicated by analysis. The multiplicities of available sites in a structure are characteristic of the space group to which the structure belongs. If chemical analysis produces a unit cell formula inconsistent with the observed space group and its associated site multiplicities, then one or the other must be wrong. Usually it is the proposed formula that is found to be in error.

A unit cell of crystalline material ideally contains a whole number of formula units. Knowing the symmetry and multiplicities of a structure can often clarify or correct a chemical formula in cases where analytical data are poor. If the chemistry is well known and the symmetry highly specialized, a structure can sometimes be solved by inspection. Symmetry requirements predict the number of structural positions available for various types of atoms; atomic size information and likely bond distances can then sometimes allow atoms to be simply assigned structural sites, where no other choices are possible. Obviously, very few substances remain to be studied whose structures can be so easily solved.

The high-speed modern computer is an essential tool in X-ray structure analysis. The position of an atom in a structure is specified by its three spatial coordinates within a unit cell. Crystals can have as few as one or as many as fifty or more atoms (in the case of inorganic materials) whose positions must be individually determined. In addition, at all temperatures above absolute zero, atoms are in motion. Thermal motion takes the form of a vibration, or oscillation, of an atom about a mean (central) position, and thermal motion increases at higher temperatures. At very high temperatures thermal agitation in a crystal becomes so violent that bonds between atoms are broken, and the substance decomposes, assumes a new structural arrangement, or melts. But thermal motions in crystals are seldom equal in all directions (spherically symmetrical); rather, vibration is usually most extreme in one particular direction. The vibrating atom usually is best described in terms of an ellipsoid, the three semi-axes of which indicate the extent of vibration in three dimensions.

Thus, a full description of thermal motion of atoms requires three parameters for each atom; to account for this motion in 50 atoms adds enormous complexity to the solution of crystal structures. To further compound the difficulties, atoms are linked together in crystals by chemical bonds. The movements of one atom therefore affect those of all others in the immediate vicinity. A general description of the complete interaction is unimaginably complex. In fact, structures containing many independent (non symmetrically-equivalent) atoms would be insoluble without the aid of computers. Some idea can be given of the size of the calculations involved.

One can calculate, by hand, using logarithmic and trigonometric tables, the expected intensity of a particular diffracted beam arising from a structural model. The writer has performed this calculation for a structure containing 19 separately-describable atoms, ignoring thermal motions. A single reflection could be done in about an hour, after simplifying the chore by combining the atoms (by kind) into about 5 groups. The high-speed computer can do the same calculation treating all 19 atoms independently, for about 5,000 reflections, in less than 10 minutes.

The power of the computer goes beyond this. In a minute or two the data calculated by the computer can be compared with those obtained from a real crystal, and the model *itself* changed within the memory of the computer. The atom positions are adjusted (all automatically) to give a model that gives calculated data matching more closely the observed data. This process is continued over and over again until additional changes in the model do not result in better agreement with the observations. The best possible model is thus obtained.

One "super-program" has been written that concatenates a series of programs to correct experimental data, calculate a trial model and refine it in a continuous operation. Data from a real crystal are entered as input, along with restrictions based on chemical analysis. After correcting these data for such factors as X-ray absorption by the specimen, the computer uses probability techniques to assign phases to certain strong reflections and thereby create a trial model. The final step is refinement of this model and printout of a list of all the atoms in the structure, with their refined positions. Oddly enough, mineral structures seem to be the most resistant to this kind of analysis, while far more complex organic molecules are usually determined with little difficulty.

The benefits of detailed structural information are many. Knowledge of accurate interatomic distances in crystals has led to generalization of these values for a variety of structure types, and has led to a better understanding of atomic bonds. The ultimate result of such knowledge is often the creation of new materials, tailor-made for specific applications. Crystallographic information, in a strange circle of coincidence, enables scientists to create the materials needed for progress in computer technology, thus further advancing the science of crystallography.

Very accurate structural information tells us the distribution of specific types of atoms among certain structural sites. It has been discovered that this distribution is sensitive to conditions in which the crystal formed: such information is invaluable to mineralogists seeking better understanding of processes, occurring deep within the earth, that are out of reach of direct observation.

Single crystal techniques give detailed information about crystal symmetry, as well as indications of structural arrangement. In this sense they are among the most powerful techniques in the experimental-arsenal of the crystallographer. They all suffer, however, from one major disadvantage—the necessity of having a good single crystal (this can actually be defined as a fragment of homogeneous crystalline material of sufficient size to give reasonable diffraction intensities in a reasonable time). Grains as small as 0.05 mm are usable. Sometimes crystals even this small are simply not available.

Happily, methods do exist for obtaining X-ray data from powders. Since powder methods are easier

(Continued on page 144)

Specimen Requests

Anyone having samples of a mineral described as "pale-blue, hexagonal, micaceous" from either Salida, Colorado (where it occurs with serpierite and linarite) or the old Ecton mine, Pennsylvania (found with serpierite and devilline), please send any you can spare to:

Miss Mary Mrose
Rm G 241 H
G.S.A. Building
U.S. Geological Survey
Washington, D.C. 21242

Needed! Greenalite from the type locality—the Mesabi district, Minnesota. The Smithsonian Institution does not have any of this mineral in its collections and would like to acquire some. Please send to:

Dr. Joel E. Arem
Division of Mineralogy
Smithsonian Institution
Washington, D.C. 20560

I am working as a Research Scholar here, and have been engaged in the study of dislocations in natural and synthetic single crystals of $CaWO_4$, called scheelite by mineralogists. I am keenly interested in looking for the growth features or microstructures such as spirals, natural pitting or hillocks, shieves, dendrites, etc., on the as-grown surfaces of these crystals.

I need a few good and cleavable specimens to help me pursue this research. Any usable material sent via AIR MAIL as soon as possible would be greatly appreciated. Thank you.

Satish K. Arora
Dept. of Physics
Sardar Patel University
Vallabh Vidyanagar
Gujarat, India

I noted your editorial "Mineralogical Fellowship" in the Jan.-Feb. issue. The Greylock and Northern Berkshire Mineral Clubs have a joint project to start a mineral museum for the Berkshire Community College when the new $11,000,000 campus is completed next Fall or in the Spring of 1972. Concurrently we are assembling a collection for a local elementary-junior high school for which cabinets have been purchased.

The members of the clubs made the first contributions of nearly 100 specimens. Realizing that the future quality of the collection will depend somewhat on the initial standards the gifts of the members were made at some personal sacrifice from their own collections. Now we are seeking and getting assistance from other museums, private companies and individuals. The results so far are very gratifying but we have a long way to go to obtain the size and quality of collection we wish to make available for the geology and mineralogy students at the college now and in the many years to come.

Your editorial indicates you wish the Mineralogical Record to become a vehicle through which such projects can be accomplished. Possibly some readers might wish to help us make our gift to the college a really fine one. Of course, fine crystal specimens are being sought for the museum but for study purposes, specimens of lesser quality will assist students in the learning process. Thus all specimens will be welcome. Perhaps you will publish this appeal and some of your readers will be able to help us. Acknowledgement of the donor will be included on the label.

G. Fred Lincks, Chairman
College Mineral Collection
Committee
867 West Street
Pittsfield, Mass. 01201

As a collector, I personally liked your Specimen Request column, in the Fall 1970 issue. It so happened that I was reading this article while enroute to Atlanta, Georgia and upon arrival I contacted Dr. Stephen Spooner, Associate Professor of Metallurgy at the Nuclear Research Center and had quite a pleasant chat with him. We have since corresponded and I have sent him, not the siderite mentioned, but several specimens of hematite and unusual crystal growths on the stalactitic formations found in a cave in Alleghany County, Virginia.

It is just this type thing that adds to the pleasure of collecting—the feeling that in some small way we may contribute the needed specimens to further studies. I have also been successful in getting our Appomattox Gem and Mineral Society to have as one of our projects, offer to furnish any specimens we can to such requests as may be listed in your fine magazine.

R. C. Gillespie
Richmond, Virginia

Four of a Kind

Paul Yaffe
Baltimore, Maryland

Collectors of minerals may differ in certain respects from their counterparts in other fields but in at least one respect they are more alike than different: they have a need to let others know something of the nature and quality of their collections. This sharing of the awe and pleasure they gain from their viewer's pleasure serves to reinforce the collector's enjoyment as well. The satisfaction of the collector is the consequence of a creative act in the sense that he may feel he is responsible for creating the pleasure in the viewer. Such a situation is somewhat analagous to what transpires when two people share their love for one another. The collector of minerals, no matter what else may motivate his collecting, is surely having a love affair with his collection.

Being a teacher for many years, I have come to expect the greatest gratification from eliciting contributions from children that represent an output of their own resources rather than a rote recall of something I said or something they read. I see my role as catalyst and stimulator rather than a fount of knowledge.

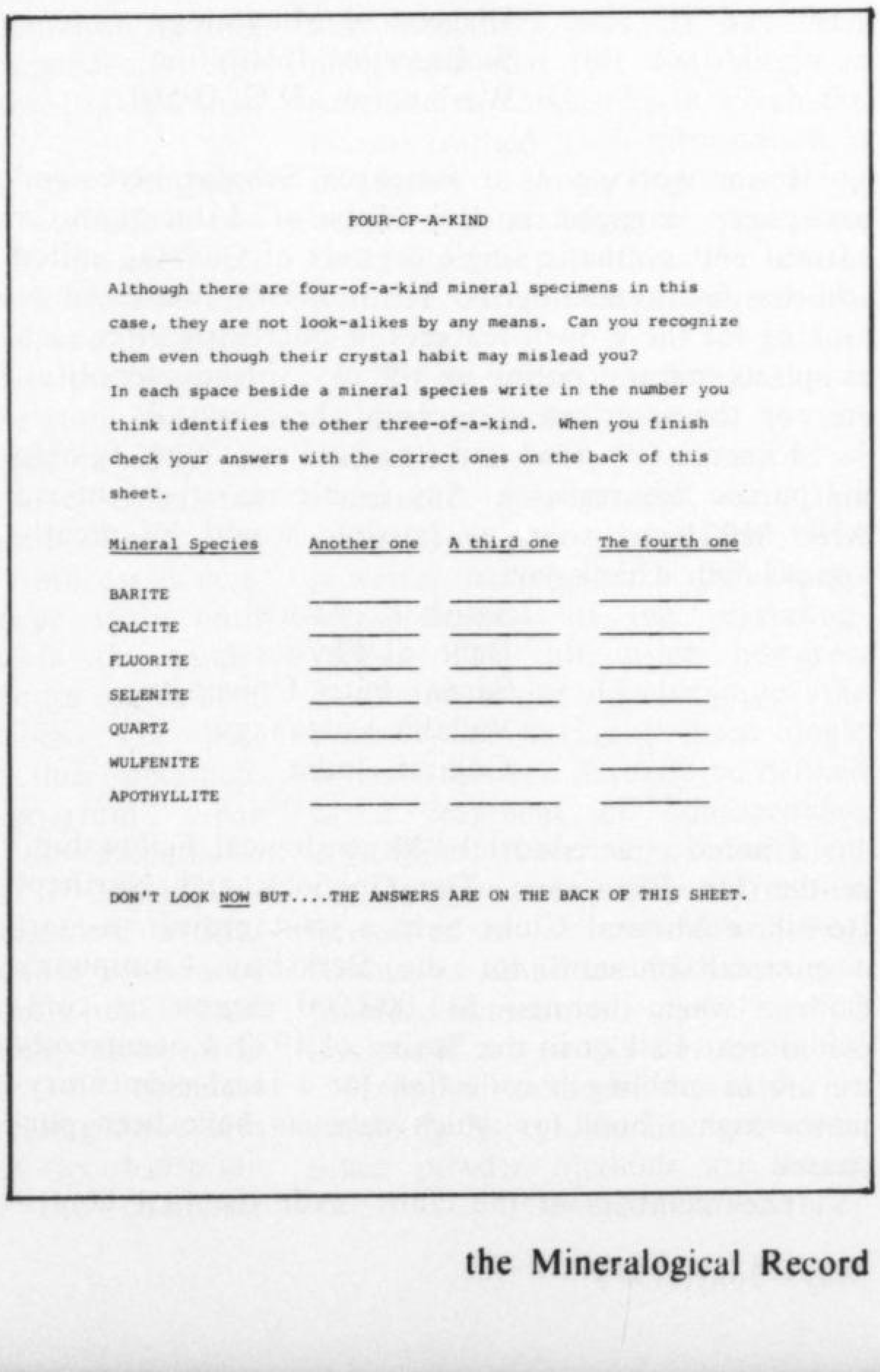
As a consequence of this background and philosophic point of view, I began to toy with an idea for an educational exhibit of mineral specimens that might seduce the passive viewer into a more active participation with the objects in the exhibit. Very candidly, if not quite sportsmanlike, I aimed at one of man's more vulnerable spots: his need to play detective, to solve puzzles and riddles. And so the idea for an exhibit that would be more than a casual viewing experience took shape.

Much of the delight and wonder that mineral specimens stir in me stems from the perfection and beauty I find in crystallized examples and from the diversity of form encountered within a given species. These characteristics are to be found in the seven mineral species I selected as the core of the exhibit: Barite, Quartz, Calcite, Selenite, Wulfenite, Fluorite, and Apophyllite. These species happen to be well represented in my collection.

'On a raised platform in the case, one specimen of each species was placed, correctly labeled in accordance with uniform rules. Each specimen was of choice quality and exhibited the characteristic color and crystal habit of the species.

On the floor of the case three more examples of each of the seven species were dispersed without regard for the species to which they belonged. Furthermore, these were labeled only with a number from 1 to 21; no other identification was provided. Needless to say, the "four of a kind" specimens bore little obvious resemblance among themselves and herein lay the task of the viewer.

Each viewer was given a pencil and mimeographed directions as follows:



FOUR-CF-A-KIND

Although there are four-of-a-kind mineral specimens in this case, they are not look-alikes by any means. Can you recognize them even though their crystal habit may mislead you?
In each space beside a mineral species write in the number you think identifies the other three-of-a-kind. When you finish check your answers with the correct ones on the back of this sheet.

Mineral Species	Another one	A third one	The fourth one
BARITE			
CALCITE			
FLUORITE			
SELENITE			
QUARTZ			
WULFENITE			
APOTHYLLITE			

DON'T LOOK NOW BUT....THE ANSWERS ARE ON THE BACK OF THIS SHEET.

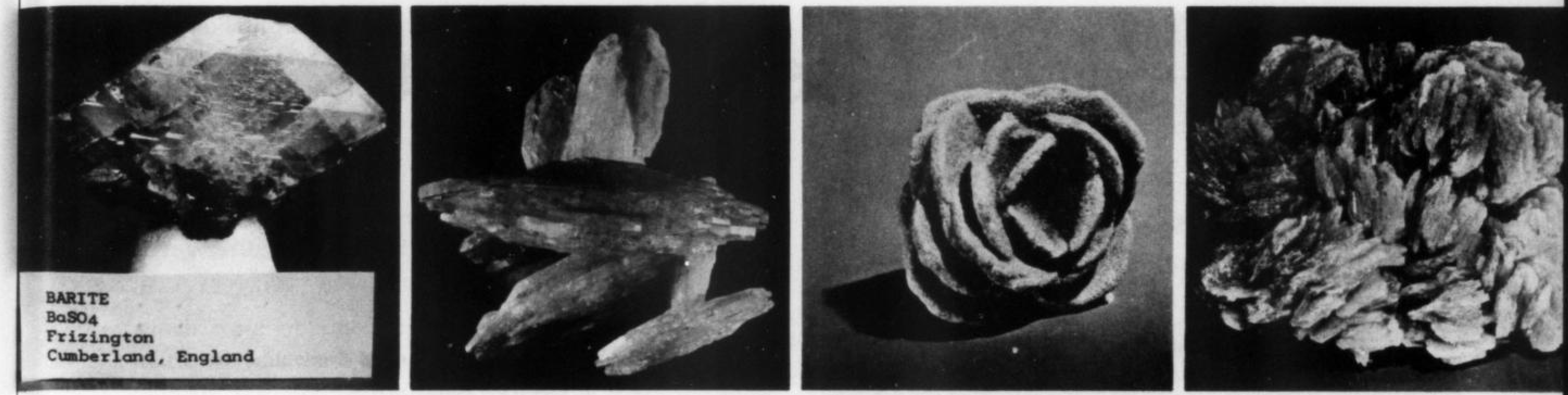


Fig. 1. Four specimens of barite chosen for a "Four of a Kind" display. The specimen on the left is labeled, the others are assigned random numbers. **Photos by Joel E. Arem**

Although I had planned it with what I considered sound educational principles in mind, the exhibit was nonetheless an experiment and as such had to prove itself in practice. An educational technique may be quite effective when it has been planned with a known group in mind, but with an undifferentiated group the results may be very different indeed. Mineral and earth science shows attract people from many walks of life, including the most sophisticated and the most naive, young and old alike. At whom, then, is this particular exhibit aimed?

This question, I learned later, proved a bone of contention when it was raised by one of the jurors judging the exhibits. I cannot comment on the views expressed as I was not a party to the discussion but I should like to address myself to the question itself since I consider the question valid and one probably raised by others than the jury.

Sponsors of any show to which the public is admitted without regard to the background and qualifications of those seeking admission must surely have grappled with the question, "For whom are we planning this show?". And whether or not they have resolved the question to their own satisfaction, it is this writer's belief that the answer is really a foregone conclusion. Each person will benefit from the show in direct proportion to the background of experiences he brings to the show. One individual's background may equip him only to recognize that mineral specimens are often pretty and for him this may constitute a legitimate increment to his concept of minerals: minerals are a source of esthetic experience. Another may spend but a brief moment on the esthetic aspects in order that he might immerse himself in the complexity of crystal structure, and the like. Dr. Pough stopped to admire one of my exhibits but I would venture to suggest that his enthusiasm was not a whit more sincerely experienced than that of a voluble five-year old who was exploring a new world at his level of experience.

Within this context, then, such educational exhibits offer something for everyone—for everyone, that is, who stops to look. If he does stop to look, our observation indicates, the likelihood is he will pause for a longer and more discriminating look even if he doesn't stay long enough to "play the game". If he stops and does play the game, it is our contention that the observer will learn that minerals with the same name and chemical composition may vary remarkably in form, color and general appearance; that minerals occur in many and widely dispersed geographic areas; that the mineral locality may influence the characteristics of given minerals; and, at the very least, that minerals can be astonishingly beautiful. For me, this final realization is sound enough rationale for mounting an exhibit for the general public.

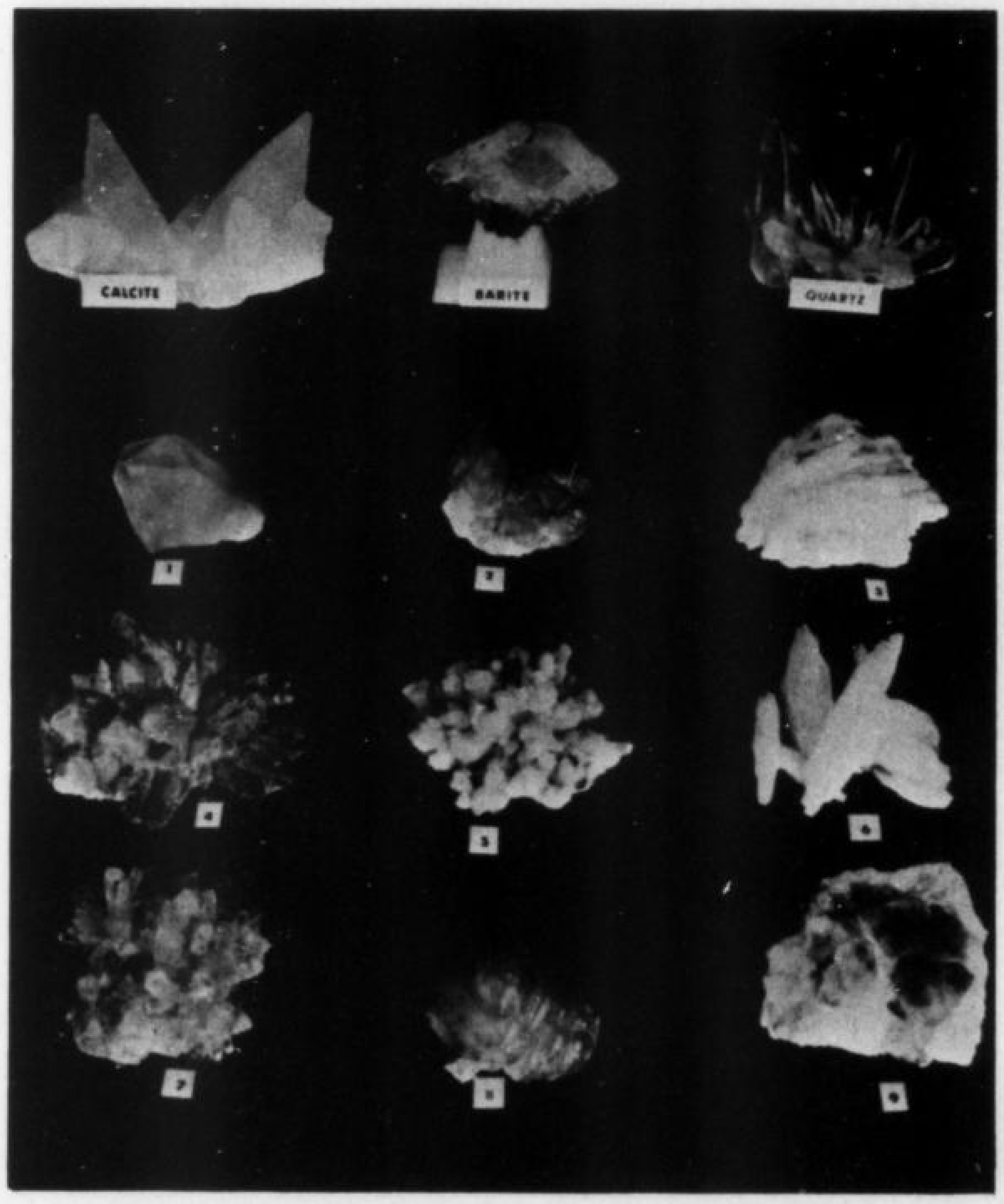


Fig. 2. Possible arrangement of a "Four of a Kind" display. The exhibitor may use more than 3 different minerals. The calcites are 4, 7, 8; barites 3, 5, 6; and quartzes 1, 2, 9.

Chalcoalumite from Bisbee, Arizona

S. A. Williams and BaSaw Khin
Phelps Dodge Corporation, Douglas, Arizona

In February of 1971 a local mineral collector, Terry D. Mayberry, brought in a blue crystalline mineral found in the Sacramento pit at Bisbee which we identified as chalcoalumite, $CuAl_4(SO_4)(OH)_{12}\cdot 3H_2O$. We have subsequently found more material in the company's storage bins at Bisbee, but nothing as striking as the first sample.

In all of these samples the chalcoalumite occurs in vugs in a dense quartz-goethite gossan. Cuprite and malachite are also common. The chalcoalumite is beautifully crystallized either directly upon the matrix or perched on corroded cuprite crystals. Some also occurs in pockets of coarse fibrous malachite which grades into pale green malachite needles towards the center of the pocket. These needles may impale tiny but highly perfect chalcoalumite crystals. In much of this material the chalcoalumite is completely altered to massive, botryoidal gibbsite of pale blue color. The material with crystalline chalcoalumite also differs from the specimens found during the past year in the Sacramento pit. These older specimens consist of massive microcrystalline to fibrous chalcoalumite thickly encrusting azurite or malachite.

Commonly the chalcoalumite occurs in small spherules of pale blue color. These spherules are comprised of small, highly perfect crystals (0.5 mm in diameter) which project outward in all directions and, individually, are perfectly transparent and nearly colorless. The crystals are sectile and show a perfect cleavage on {100}.

The original description by Larsen and Vassar[1] (1925) was based on microcrystalline material decidedly inferior to the newly discovered crystals. They considered chalcoalumite to be triclinic. We have studied the crystals goniometrically and by various X-ray techniques and find that they are monoclinic sphenoidal.

Single crystals of both hands appear to be equally abundant. In habit these are triangles, almost perfectly equilateral, with the flat side bounded by {100}, one edge by {010} and the other two edges by {012} and {11$\bar{2}$}. Such a crystal (right handed) is shown in Figure 1. An angle table is given in Table 1.

Twinning is common and three laws are found. Most common are twins in {100} and in {010}. Twins in {100} closely resembly untwinned crystals but are easily detected in polarized light when viewed normal to {100} for they have no extinction position—a feature previously noted by Larsen and Vassar but ascribed only to strong dispersion. Twins in {010} form diamond-shaped tablets but commonly the composition plane is sutured and may even show internal reflections. Both of these twin laws are also shown in Figure 1.

Table 1
Morphological Data for Right-Handed Chalcoalumite

a:b:c = 1.917:1:1.1464 β = 95°53′
P′o = .601 q′o = 1.146 X′o = .103

hkl	ϕ	ρ	ϕ_2	ρ_2	C	A
100	90°00′	90°00′	0°00′	90°00′	84°07′	0°00′
010	0°00′	90°00′	....	0°00′	90°00′	90°00′
012	10°12′	30°13′	84°07′	60°19′	29°42′	84°54′
11$\bar{2}$	-19°01′	31°14′	101°10′	60°39′	33°34′	89°43′
13$\bar{6}$*	0°17′	29°50′	89°50′	60°11′	30°19′	89°52′

*not a morphological form

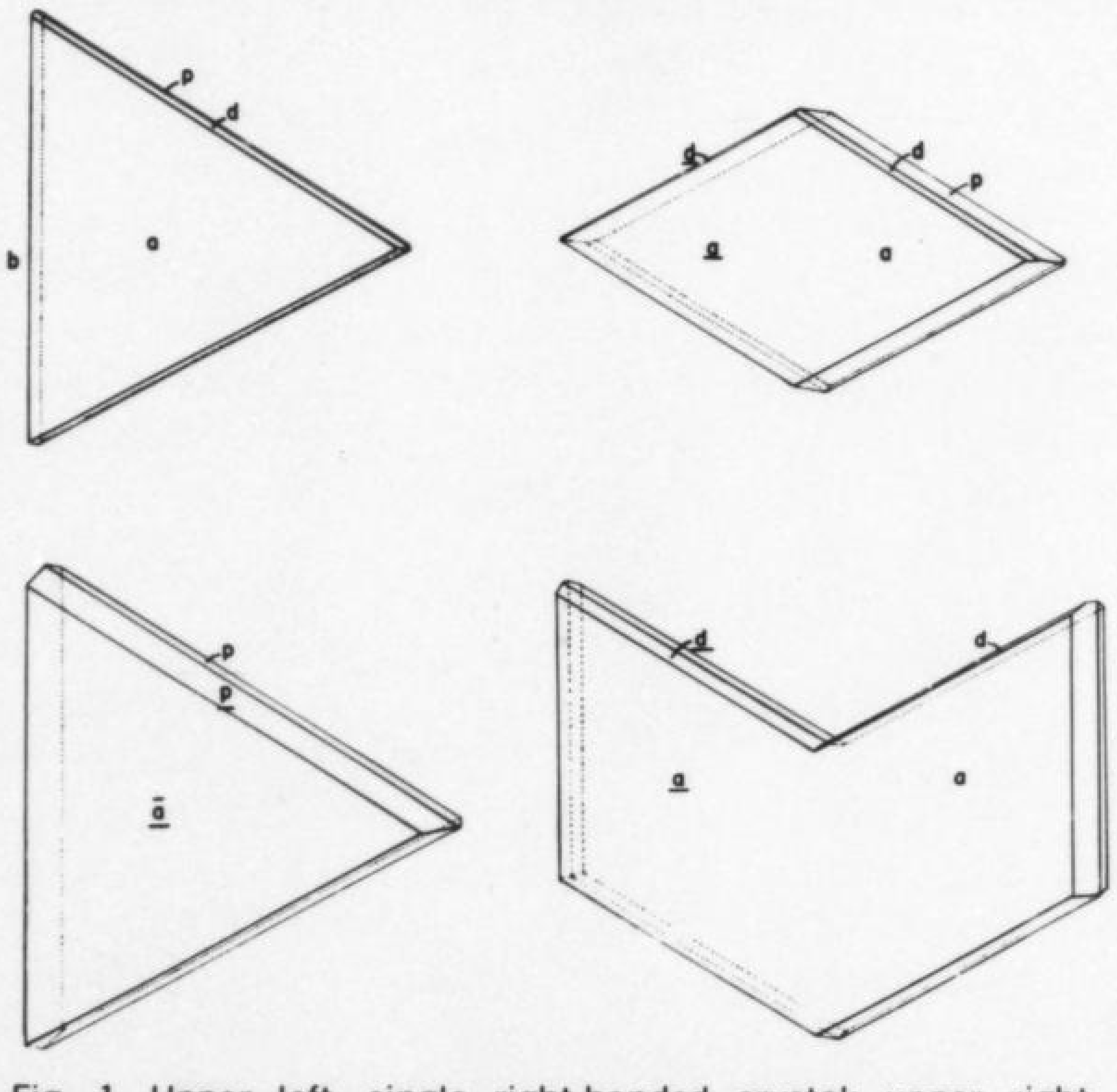


Fig. 1. Upper left, single right-handed crystal; upper right, twin in {010}; lower left, twin in {100}; lower right, twin in {13$\bar{6}$} and {010}. Forms are a {100}, b {010}, d {012} and p {11$\bar{2}$}.

Less common is twinning in {13$\bar{6}$} which is a pseudoorthorhombic third order prism. Such twins may have a deep reentrant as shown in Figure 1; the composition plane may be {100} or {13$\bar{6}$}. All or some of these laws may occur together. Eightlings and fourlings based on the {13$\bar{6}$} and {100} laws are

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[1] Larsen, E. S., and H. E. Vassar (1925) Chalcoalumite, a new mineral from Bisbee, Arizona. *Amer. Mineral.* **10**, 79-83.

common. Equally common are diamond-shaped eightlings based on all three laws.

The morphological evidence for sphenoidal symmetry is strong. This symmetry was confirmed by etching of untwinned crystals in concentrated cold NH_4OH and 20% $HgCl_2$.

A unit cell was chosen on the basis of single crystal X-ray patterns. The cell has the following parameters:

$a = 17.090Å \quad b = 8.915 \quad c = 10.221 \quad \beta = 95°53'$

which were obtained by refining powder data. Systematic extinctions in the Weissenberg photographs indicate the space group $P2_1$. This cell gives a calculated density of 2.25 (with Z = 4) as compared with Larsen and Vassar's measured value of 2.29. The indexed powder pattern is given in Table 2.

The optic orientation is $Y = b, Z \wedge c = +22°$ and $2V(+)$ is 61° at 430 mμ and decreases to 46° at 620 mμ. Just the opposite dispersion is reported by Larsen and Vassar, perhaps arising from observations on twinned crystals. Pleochroism is feeble (even in larger crystals) with X = pale green, Z = robins egg blue, and Y colorless. Optical activity was sought but not found.

Table 2
Indexed Powder Data for Chalcoalumite
Cr/V Radiation, 114 mm Wilson Camera

I/I₀*	d obs. Å	d calc. Å	hkl
100	8.502	8.500	200
22	7.898	7.895	110
9	6.705	6.703	011
6	6.393	6.385	$11\bar{1}$
8	6.103	6.097	111
8	5.445	5.446	$21\bar{1}$
13	5.100	5.098	211
22	4.786	4.782	310
9	4.573	4.574	$20\bar{2}$
6	4.314	4.312	120
91	4.250	4.250	400
23	4.178	4.178	202
3	3.849	3.836	410
5	3.705	3.704	$41\bar{1}$
6	3.501	3.504	320
5	3.335	3.331	$11\bar{2}$
9	3.177	3.177	510
9	3.059	3.062	213
		3.066	$11\bar{3}$
		3.050	$30\bar{3}$
5	2.822	2.818	$31\bar{2}$
		2.826	$13\bar{1}$
8	2.726	2.723	$42\bar{2}$
		2.728	$23\bar{1}$
8	2.633	2.632	123
		2.632	330
		2.634	$22\bar{3}$
7	2.585	2.585	512
11	2.520	2.518	132
		2.519	331

plus 14 additional lines to 1.191A

*measured photometrically

We are grateful to Terry D. Mayberry for bringing the sample to our attention. F. B. Millett provided assistance in the computations involved in indexing and refining the cell.

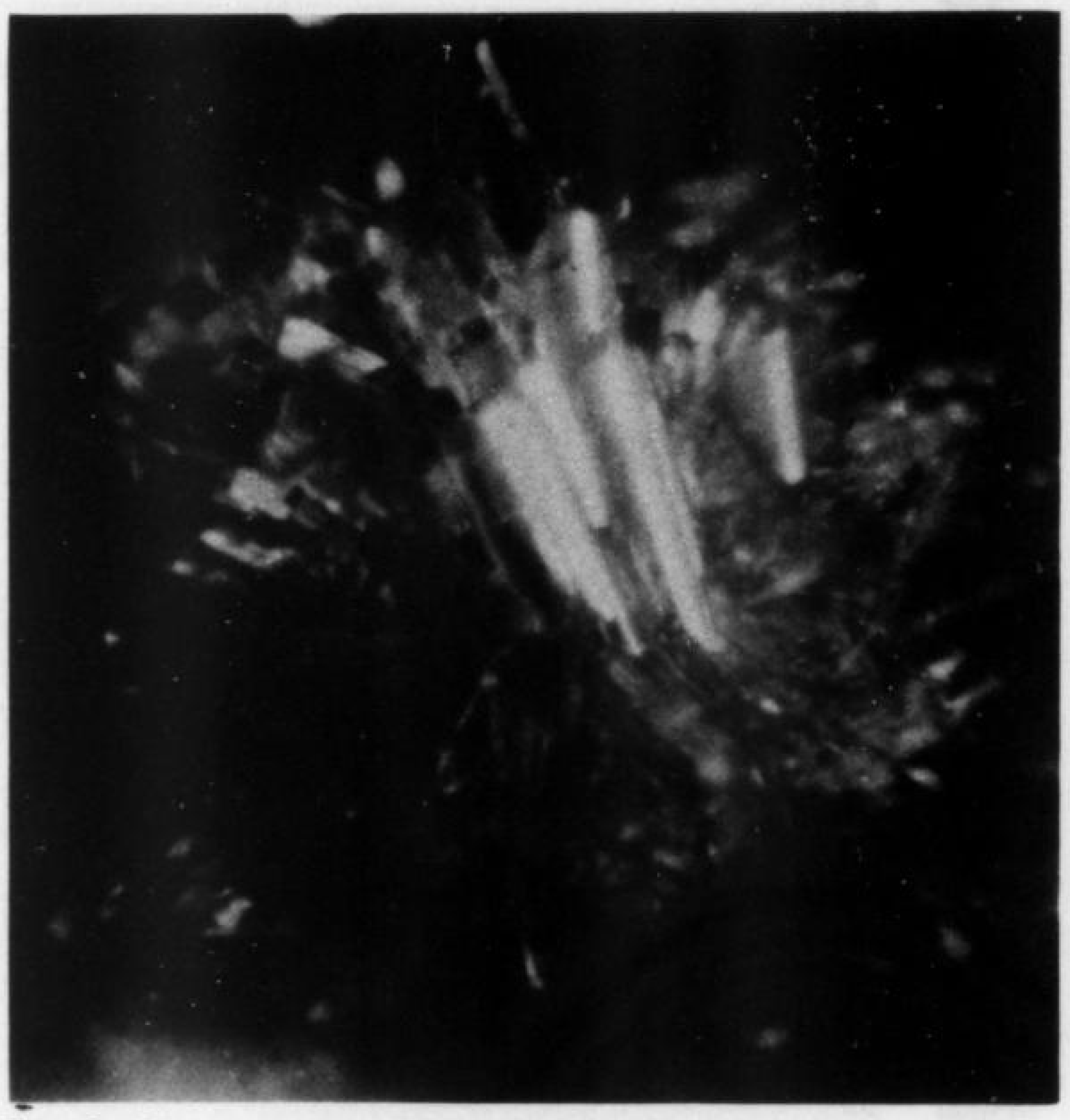


Fig. 2. Cluster of chalcoalumite crystals. Some twinning in {100} may be detected. Crystals about 0.4 mm on an edge.

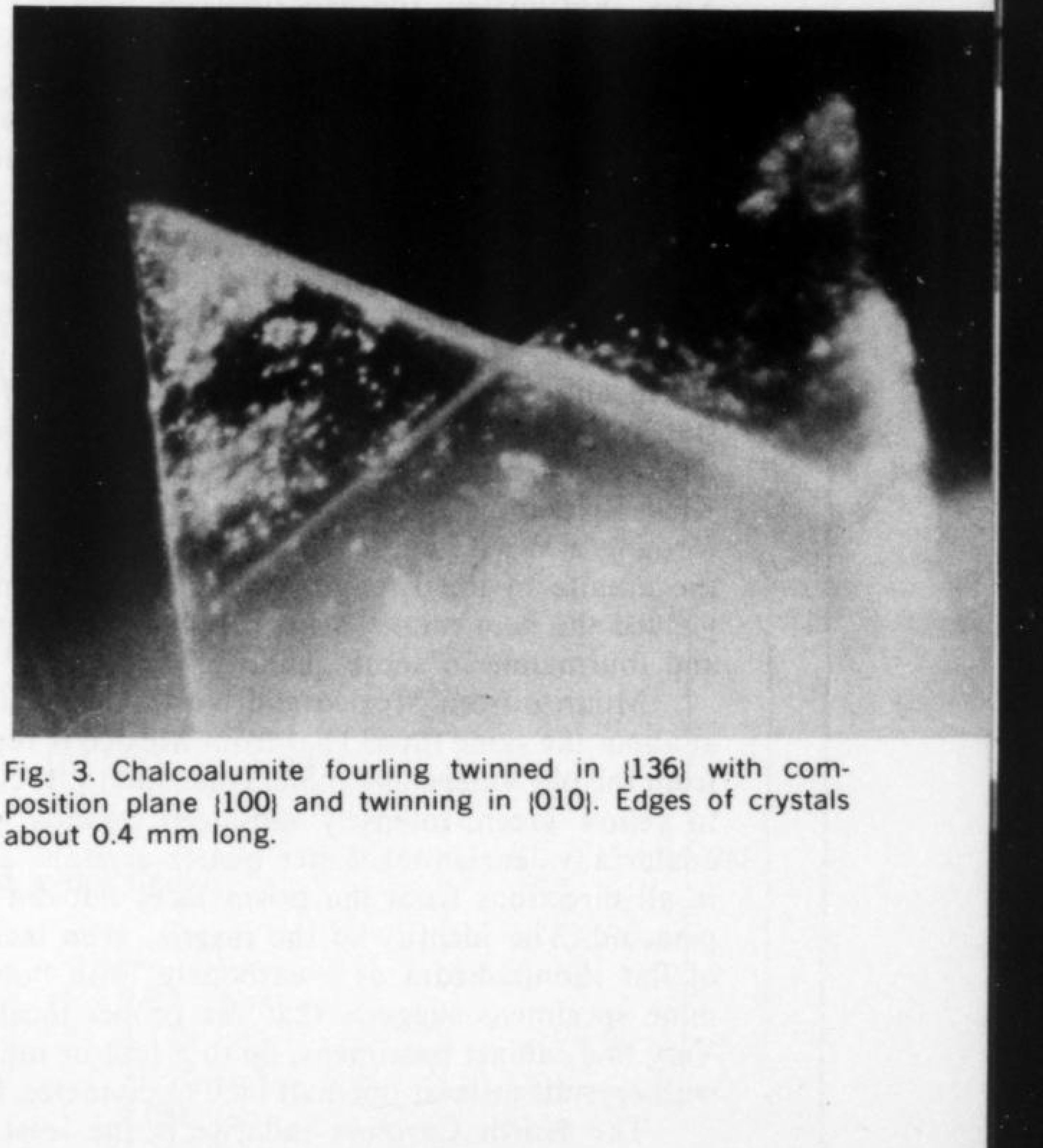
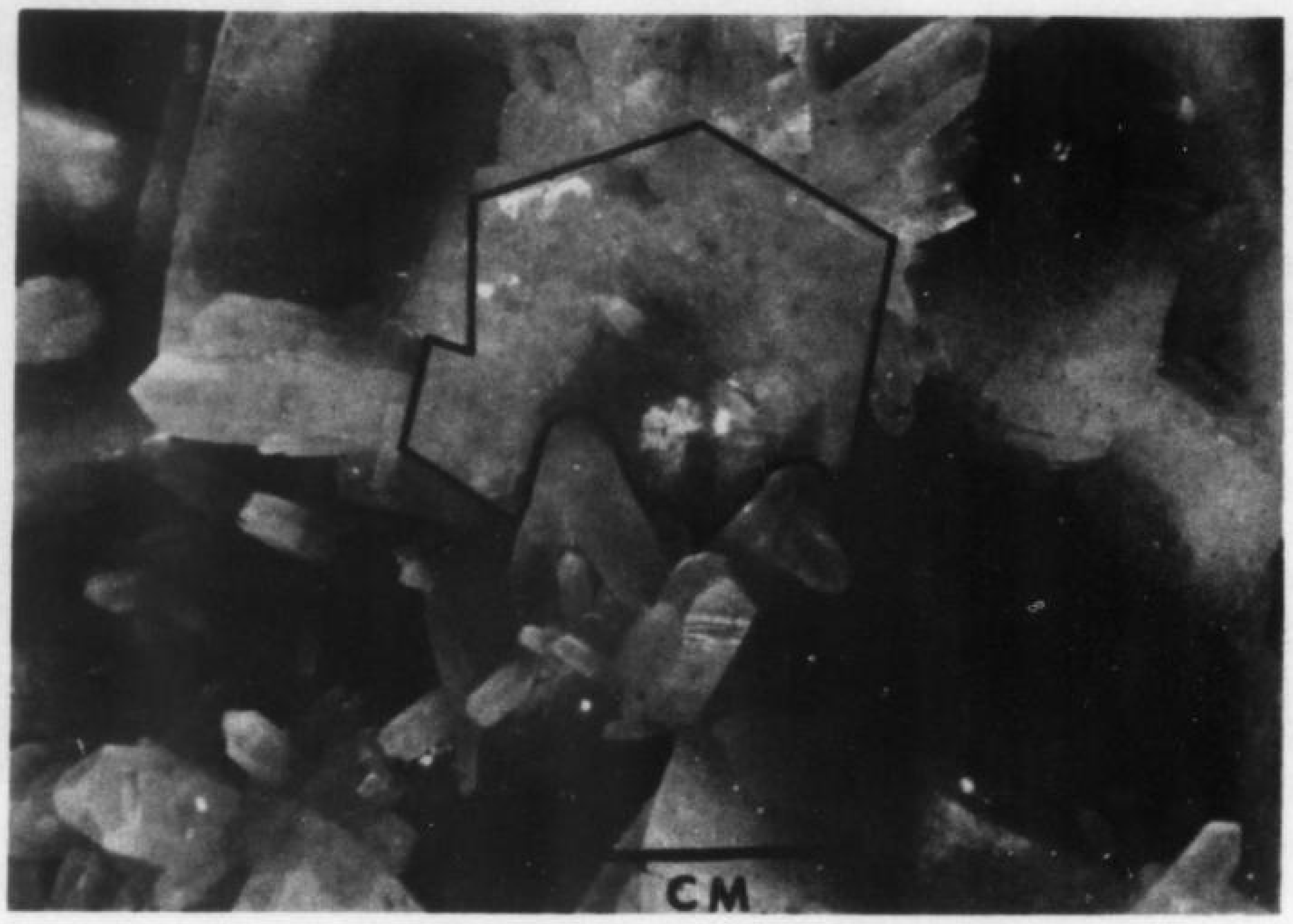


Fig. 3. Chalcoalumite fourling twinned in {136} with composition plane {100} and twinning in {010}. Edges of crystals about 0.4 mm long.

what's new in minerals

Milarite

It is quite rare when a mineral, long considered very rare, suddenly appears at three new localities, and is very plentiful in two of these localities. Milarite is such a mineral. Its former occurrence has been pretty much limited to the Upper Val Giuv and Upper Val Strem regions of Switzerland, and at Vezna in Western Moravia, Czechoslovakia.



Milarite crystal outlined in ink. Guanajuato, Mexico. **Photo by Joel E. Arem.**

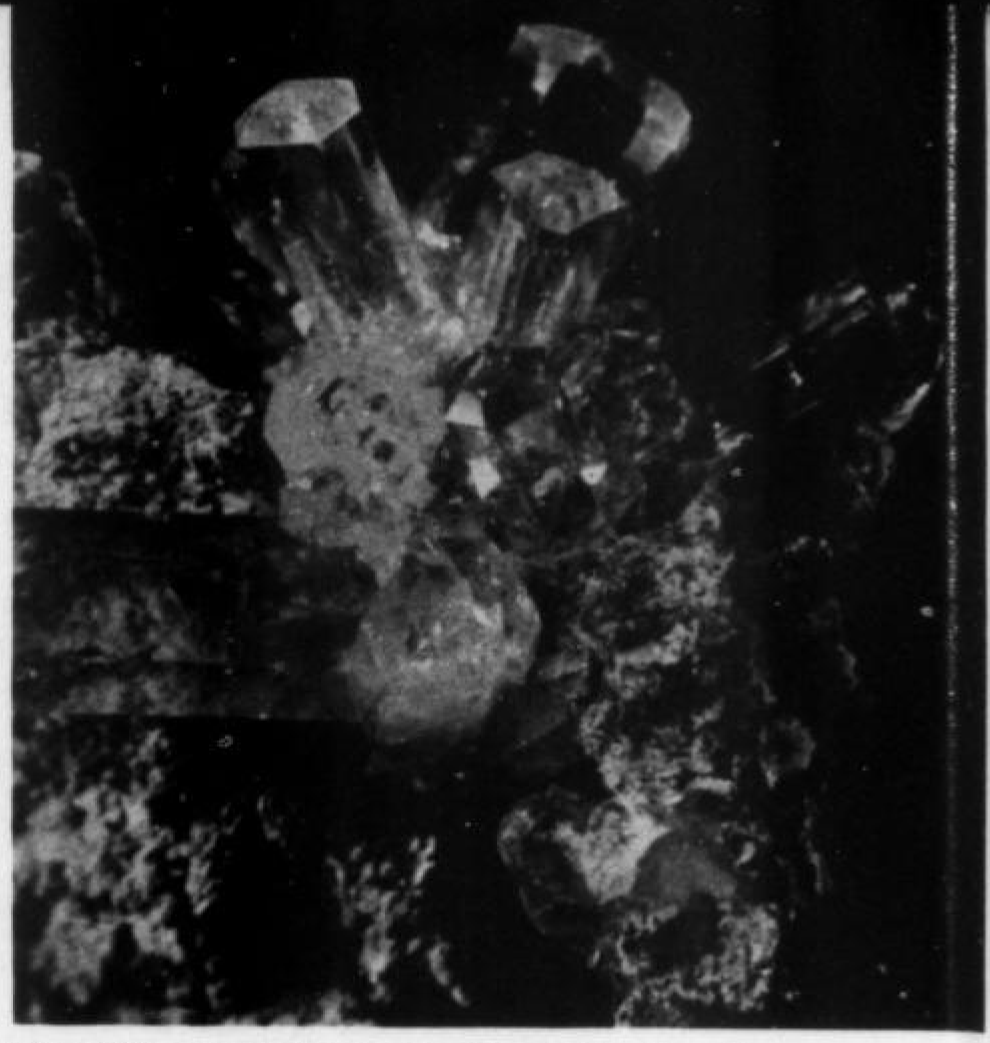
The string of more recent discoveries of milarite began several years ago when the Smithsonian identified as milarite material being sold as chrysoberyl by a mineral dealer in New York. Fortunately the Museum was able to acquire the dealer's entire stock, consisting of nearly fifty specimens, many as loose crystals. It was thought at the time that these were probably the ultimate in milarite as they came in beautiful yellow-green crystals, in part transparent, up to 1 inch in length and one-half inch wide. The crystals are embedded in zoned (beige to white to grey) calcite. The only other minerals observed are tabular twinned crystals of albite and quartz of a medium smoky color.

The locality is given as near Rössing, Swakopmund, Southwest Africa. There appears to be considerable confusion surrounding localities in this region. Spencer (*Min. Mag.*, **23,** 622, 1934) states "Many specimens labelled 'Namib Desert,' 'Spitzkopje', 'Neu Schwaben,' 'Usakos,' and 'Rössing' are no doubt from Klein Spitzkopje . . . The Klein (Little) Spitzkopje is a granite hill forming a WSW. outlier, beyond the Gross (Great) Spitzkopje, of the granite of the Erongo Mountains in Damaraland . . . It has yielded the gem minerals beryl (aquamarine and heliodor), topaz, and tourmaline in some quantity."

Milarite from Mexico and North Carolina appeared next and at about the same time. That from Mexico is reported to have come from the old Valenciana mine, Guanajuato. It consists of lime green to yellow green, intensely mosaiced crystals growing upon white adularia (valencianite). Later quartz crystals, also white, stick out in all directions from the prism faces but did not grow upon the pinacoid. The identity of the matrix, even including the presence of flat rhombohedra of a carbonate, with "old-time" Valenciana mine specimens suggests that the proper locality has been given. Very fine cabinet specimens, up to a foot or more in one dimension with crystals at least one-half inch in diameter, have been available.

The North Carolina milarite is the least spectacular of the three. It is found in the Li-Sn pegmatite being mined for spodumene by the Foote Mineral Company. The mine is near Kings Mountain, Cleveland County. The crystals are small, about 2 - 3 mm, and consist of a simple hexagonal prism and pyramid and the pinacoid. They are white and therefore difficult to see on the white albite crystals with which they tend to be associated. Milarite may be regarded as one of the rarer minerals at the Foote mine and specimens are not available.

continued in next column



Mimetite crystal spray. Tsumeb, Southwest Africa. **Photo by Joel E. Arem.**

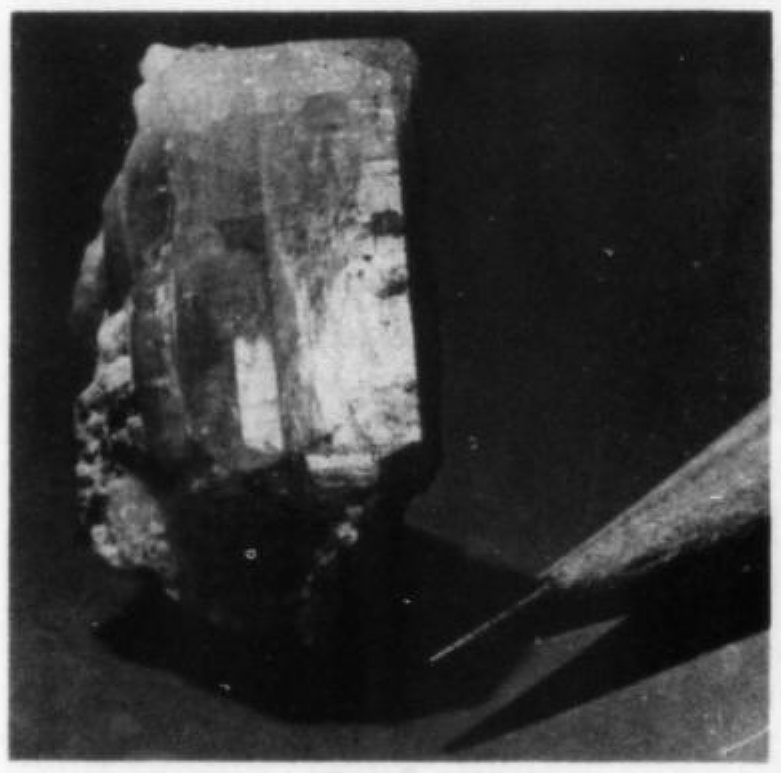
Mimetite

Mimetite from Tsumeb, Southwest Africa, has long been recognized as outstanding and is much sought after. A new find, however, at Tsumeb is even better than the older material, to the point of challenging one's credulity. The crystals are absolutely transparent, very pale yellow (Chablis-colored), simple hexagonal prisms with one pyramid and the pinacoid. The luster is every bit as brilliant as that of cerussite. Crystals reach an inch in length and one-fourth inch in diameter but most are somewhat smaller. All of the specimens I have seen are on matrix which is dusted with a fine greenish-yellow powder of an undetermined mineral.

Monazite

North Carolina is famed for the monazite it has produced in the past, both as ore mined from alluvial placers and as specimens taken from a decomposed gneiss and granite injected by pegmatite near Mars Hill, Madison County. A large rough crystal was found in a shaft sunk in this rock weighing approximately 60 pounds.

A new find this summer adds showiness to the appeal of the mineral from this state which always seems able to come up with something new and exciting in the way of minerals. The locality is given as near Double Shoals, Cleveland County, and was reported by Louis Shrum of Lincolnton. The find consisted of only about six specimens but these are perhaps the finest known. The crystals are free of matrix, very sharp, translucent to nearly transparent orange, and most are V-shaped twins. The largest is about one inch across. Some have very small rutile crystals on them. The new monazites were found loose in a decomposed quartz-rich dike. Some of the quartz is beautifully rutilated, the rutile being bright red in color. What next?



Milarite crystal. Swakopmund, Southwest Africa. **Photo by Joel E. Arem.**

Observations

Conversation with Dick Gaines, of Pottstown, Pennsylvania, led to his making two interesting and thought-provoking observations.

The first was that every phenacite locality he could think of is also a green microcline (amazonite) locality. I am not sure that research will bear this out but classic localities in Colorado, Virginia, Brazil, Norway, and the USSR are certainly well-known for both species. There are other phenacite localities that are not reported as amazonite occurrences but it may simply be a failure to mention its presence. On the other hand, one would be wise to look carefully for phenacite at

(continued on page 148)

MINERAL NOTES

ERNSTITE E. Seeliger and A. Mücke

Neues Jahrb. Mineral. Monatsh., 289-298, 1970

Ernstite is a yellow-brown oxidation product of eosphorite having the generalized formula $(Mn^{2+}_{1-x}Fe^{3+}_{x})Al(PO_4)(OH)_{2-x}O_x$ (x = 0-1). Relicts of eosphorite are found with the new mineral. Unlike many pseudomorphic minerals, ernstite is found in crystals in radiating aggregates 10-15 mm long. Crystals show the forms {110}, {211}, $\{\bar{2}11\}$, {100} and others. The type locality is reported as the Davib-east farm, near Karibib, Southwest Africa and the host rock is vuggy granitic pegmatite.

The unit cell volume is near that of eosphorite, but *a* and *b* are interchanged. Unlike eosphorite, ernstite is untwinned. Cleavage is good {010} and {100}.

The mineral is named in honor of Th. Ernst, professor of mineralogy, University of Erlangen-Nürnberg.

Monoclinic — space group C_{2h}^{6}-$A2/a$ or C_{s}^{4}-Aa

$a = 13.32$ $b = 10.497$ $c = 6.969$

$\beta = 90^\circ 22' \pm 20'$ $Z = 8$

Biaxial (-) $n\alpha = 1.678$ $n\beta = 1.706$ $n\gamma = 1.721$

$2V = -74^\circ$(calc.) $Z = b$, $Y \wedge \dot{c} = -4^\circ$ $r > v$

Pleochroic: X yellow-brown, Y red-brown, Z pale yellow

G 3.07(meas.) H 3 - 3-1/2

Strongest x-ray lines 2.829 (10), 2.836 (8), 2.438 (5), 4.364 (4), 3.516 (4)

META-VANURALITE Fabien Cesbron

Bull. Soc. fr. Mineral. Cristallogr., **93,** 242-249, 1970

Meta-vanuralite, $Al(UO_2)_2(VO_4)_2(OH)\cdot 8H_2O$, is a less hydrated form of vanuralite, the eleven-hydrate. The change from one to the other is *reversibly* dependent upon the humidity of the atmosphere. Meta-vanuralite is stable at 20°C in an atmosphere of relative humidity between 47 and 28%.

The type locality is the uranium-vanadium mine at Mounana, Gabon, a locality noted also for the minerals chervetite, francevillite and curienite.

VANURALITE

Monoclinic *A2/a*

$a = 10.55$, $b = 8.44$, $c = 24.52$

$\beta = 103^\circ$

$Z = 4$

META-VANURALITE

Triclinic

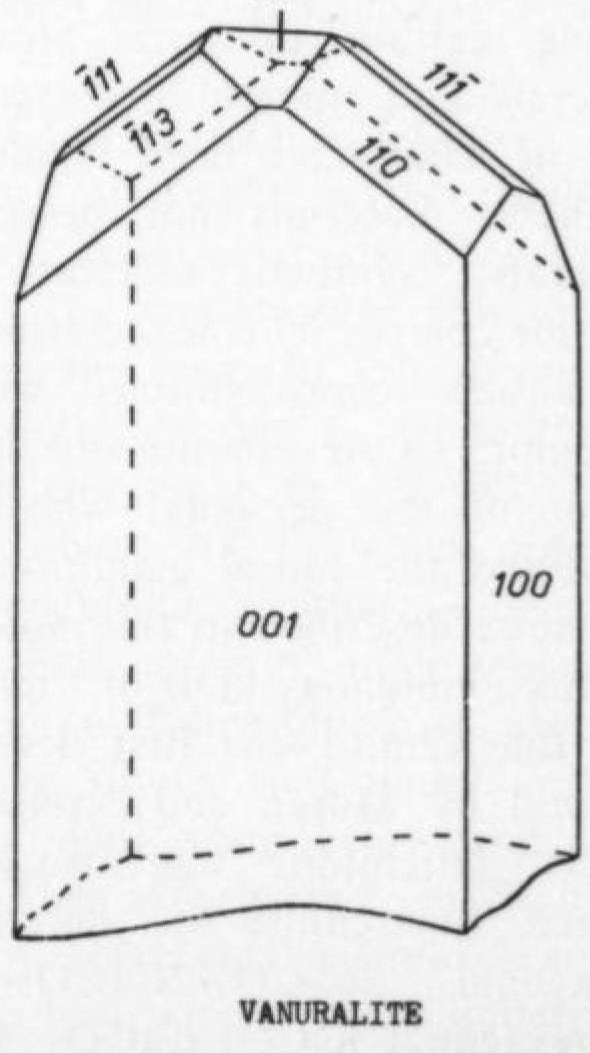
$a = 10.46$, $b = 8.44$, $c = 10.43$

$\alpha = 75^\circ 53'$, $\beta = 102^\circ 50'$, $\gamma = 90^\circ$

$Z = 2$

Strongest x-ray lines

V	M
11.98 (vvs)	9.92 (vvs)
5.98 (vs)	4.174 (vs)
3.795 (s)	3.155 (vs)
3.231 (s)	4.086 (s)
3.180 (s)	3.240 (s)



VANURALITE

An occurrence of Buetschliite East of the Rocky Mountains

By Richard V. Dietrich

Abstract.—Buetschliite, kalicinite, carbonaceous material, and quartz are constituents of fused wood-ash clinkers formed as a result of the burning of a dead, but still standing chestnut-oak tree near Long Shop, Montgomery County, Virginia. This occurrence of buetschliite is apparently the first recorded as associated with deciduous tree ash and also the first recorded for a locality east of the Rocky Mountains.

Introduction

It is well known that fire has been responsible for the destruction, modification, and formation of minerals. Examples are given in Lonsdale's (1923) report dealing with changes which took place during a museum fire and Christie's (1927) report about bararite, cryptohalite, and sulfur formed as results of a mine fire. Nonetheless, the "natural" aspect of commonly accepted definitions for the term *mineral* remains as a mental hurdle for many mineralogists in so far as calling certain of such products and occurrences minerals and mineral occurrences. Particularly when acts of Man have been involved, distinctions among synthetic materials not designated in any way as minerals, "synthetic minerals," and minerals *per se* become colored by considerations that are philosophical in nature—considerations which range from the ridiculous to the sublime and involve such things as the intent of the person(s) whose actions promoted or presented the causal conditions. The buetschliite and kalicinite described in this note constitute an example of this ambiguous kind of "mineral" occurrence.

Buetschliite was first described and defined as a mineral by Milton and Axelrod (1947). In the same report, fairchildite was also described, defined, and named. Buetschliite was described as "probably . . . hexagonal" $3K_2CO_3 \cdot 2CaCO_3 \cdot 6H_2O$ and fairchildite as hexagonal $K_2CO_3 \cdot CaCO_3$. It was hypothesized that the buetschliite was formed as the result of hydration of the fairchildite which was apparently produced by fusion and crystallization of coniferous woodash. Subsequently, however, Mrose *et al.* (1966) determined the two minerals to be polymorphic forms of $K_2Ca(CO_3)_2$; they synthesized trigonal buetschliite between 593° and 704°C and hexagonal fairchildite between 704° and 970°C.

Milton and Axelrod also noted the known natural occurrences and called attention to the facts that each involved evergreen trees within or west of the Rocky Mountains and that other occurrences had not been reported nor recalled by midwestern or eastern foresters even after they were informed of the phenomenon. Each of the recognized occurrences was described as a clinker formed by fusion and recrystallization of wood ash within a relatively large, standing tree the rotten heartwood of which had been burned.

The buetschliite described herein apparently constitutes the first recorded natural occurrence of the mineral formed as a result of the burning of a deciduous tree and also the first occurrence recorded for a locality east of the Rocky Mountains.

The Material

The investigated material consisted of a cigar-boxful of clinkers, the largest of which was about 2 cm in greatest dimension. Most of the pieces were buff to brownish gray and vesicular. Microscopic examination of broken pieces shows them to be made up of at least five different-appearing constituents: the finely granular buff-colored main mass; brownish gray coatings, up to nearly 1 mm thick and with a shrivelled or desiccated appearance, which occur on many of the original surfaces; irregularly shaped pods, up to 7 x 5 x 1 mm. in size, some of which are lined with greenish microscopic crystals and most of which are manifest by external colloform surfaces; sporadic black, shiny to dull, nearly prismatic to irregularly shaped pieces up to 2 mm. in greatest dimension; and a few scattered, nearly colorless, lath-shaped crystals which were recognized only under the microscope and then only because each gives a glint of reflected light. A minor amount of quartz, very likely wind-blown grains, also occurs in some of the clinkers.

Optical and *x*-ray data were determined for each of the materials except the colorless lath-like crystals which proved too few and too small for separation. On the basis of these data it may be said that *as of the time the material was received:* the main mass and the brownish gray coating were chiefly buetschlitte plus kalicinite, the greenish crystals were buetschlitte, and the black material consisted largely of carbonaceous material plus some kalicinite. The "as of the time . . . received" qualification is made because it would seem, on the basis of previous studies of similarly occurring fused wood-ash, that fairchildite was very likely an, and possibly the chief, original constituent. In order to assure no misunderstanding with regard to this point and this occurrence, the following statement appears warranted: no fairchildite was found in any of the clinkers, even though special efforts were made to determine the identity of the constituents of the central portions of the largest pieces as well as of the other described parts. It seems, therefore, that if fairchildite was ever present it has subsequently been changed to buetschliite. Such a change appears quite possible on the basis both of data presented by Milton and Axelrod and by Mrose *et al.* and the writer's tentative interpretation of certain D.T.A. data obtained during this investigation. Alternatively, the fused wood-ash herein described may have formed at temperatures below those at which fairchildite could form with the other existing controls.

Chemical data for the chiefly buetschliite-plus-kalicinite main mass material are given in *Table I*. Ten clinkers were crushed to fragments ranging between approximately one and four millimeters in greatest dimension. Fragments appearing to consist solely of main mass material—*i.e.*, those with no microscopically visible carbonaceous matter, green crystals or brown coating (see above)—were hand picked for the analyses. The buetschliite-kalicinite combination indicated in columns 3a and 3b of the table constitute a 68.85:25.85 (ratio-2.66:1) mixture. The remarkably close agreement between corresponding percentages in columns 2 and 3c considered in conjunction with the method of sample preparation suggests that the composition of the main mass of the different clinkers is extraordinarily consistent. It has not been established as to how the elements other than the bulk of the silicon, calcium, potassium, hydrogen, carbon, and oxygen occur. Perhaps reporting them as oxides on the table is misleading.

Table I

	1	2		3		
				a	b	c
SiO_2	0.38	.43	(d)			
P_2O_5	6.58	1.96	(w)			
Al_2O_3	.99	0.19	(d)			
Fe_2O_3		0.15	(b)			
CaO	21.90	16.20	(b)	16.2		/ 16.2
MgO	4.48	0.51	(b)			
Mn_3O_4	1.32	0.24	(b)			
K_2O	24.54	40.40	(b)	27.19	13.21	/ 40.4
Na_2O	2.06	1.75	(b)			
CO_2	25.47	35.34	(g)	25.46	10.49	/ 35.95
H_2O-	12.28	2.38	(w)			
H_2O^+	(by diff.)	2.04	(w)		2.15	/ 2.15
	100.00	101.59				

1. Fused wood-ash, Kaniksu National Forest, Coolin, Idaho; western hemlock (Tsuga heterophylla). Kienholz, 1929.
2. Fused wood-ash, Long Shop, Virginia; chestnut oak (Quercus prinus, L.).
   - (d) spectrographic analysis by D. Ranck and N. J. Smith; analysis also indicates trace quantities of Ba, B, Cd, Co, Cu, Cr, Ni, Pb, Sn, & Ti.
   - (w) analyst J. P. Warriner; P determined gravimetrically as ammonium phosphomolybdate; P_2O_5 value is ± 0.30; H_2O^+ value is ± 0.07.
   - (b) analyst E. W. Benson; determinations by atomic absorption spectrophotometry methods as described by Pawluk (1967) with 5% HCl solution containing 10,000 micrograms La/ml. in order to eliminate interferences (especially by phosphate) in determination of some of the metals.
   - (g) analysis by Galbraith Laboratories, Inc. of Knoxville, Tennessee; percentage given is ± 0.22.
3. Theoretical composition of a) buetschliite—$K_2Ca(CO_3)_2$, b) Kalicinite—$KHCO_3$, and c) their sum based on availability of 16.2 weight percent CaO and 40.40 weight percent K_2O.

The chiefly buetschliite plus kalicinite material was also submitted to Differential Thermal Analysis. The three essentially identical thermal curves which were obtained are characterized by an endothermic doublet between about 100° and 200°C and single endothermic reactions with peaks at approximately 480°, 700°, and 1050°C. The relatively low temperature doublet is similar in shape as well as in temperature range to one previously interpreted by Beck (1946) as representing the breaking down of kalicinite according to the equation

$$2KHCO_3 \rightarrow K_2CO_3 + H_2O + CO_2.$$

Determination of the loss of weight as the result of heating of the investigated material at 350°C corroborates this interpretation. The endothermic reaction at about 480°C appears, on the basis of loss of weight upon heating of the material at 550°C, to represent the breakdown of the K_2CO_3 to K_2O and CO_2. The endothermic reaction at about 700°C, which appears to be at least in part reversible (an exothermic reaction occurs at about 650° upon cooling), may represent inversion of buetschliite to fairchildite—as already noted, Mrose *et al.* have shown that under certain conditions buetschliite is synthesized below and fairchildite above 704°C. The endothermic reaction at about 1050°C very likely represents a breakdown of the fairchildite similar to that which calcite undergoes near 1000°C.

Formation

These clinkers were formed as the result of an act of Man. One night, well after dusk, a southwestern Virginian coon hunter and his dogs treed two coons. It was so dark the hunter couldn't see the coons. He fired blindly into the tree hoping to hit one or the other or both but neither fell. Therefore, noticing that the tree was dead, he set it on fire. The burning resulted in formation of the described clinkers.

The tree was a chestnut oak (*Quercus prinus*, L.) located near Long Shop, Montgomery County, Virginia. Immediately prior to the burning, the tree would have been characterized as a hollow snag with a few live branches; rot extended throughout; the diameter of the trunk was between three and four feet. The burning took place in December with the temperatures within a few degrees of freezing and with one to two inches of snow on the ground. The clinkers were collected within a day of the burning—in fact, "while the branches which had fallen . . . were still smoldering." The material was collected from near the base of the snag "in an area that indicated it came from one of the large, near-surface, lateral roots . . . not from the center of the tree." The fact that the entire snag was burned may be attributed to the chimney-like draw situation presented by the hollow character of the tree.

Epilogue

Hopefully this report will not prompt someone who may be preoccupied with a desire to discover and name a new mineral species to become involved in fireplace experimentation and forest arson. The fact that it is now known that both conifers and at least this deciduous tree have yielded rather similarly constituted products should be at least some deterrent.

Acknowledgments. H. H. Huff supplied the original material. Dr. Henry S. Mosby of the Department of Forestry and Wildlife at Virginia Tech confirmed the identity of the tree and gathered some of the other occurrence data. Drs. E. W. Benson and J. P. Warriner of Central Michigan University and Dr. C. I. Rich of Virginia Tech aided in the determination of laboratory data. All these aids are gratefully acknowledged.

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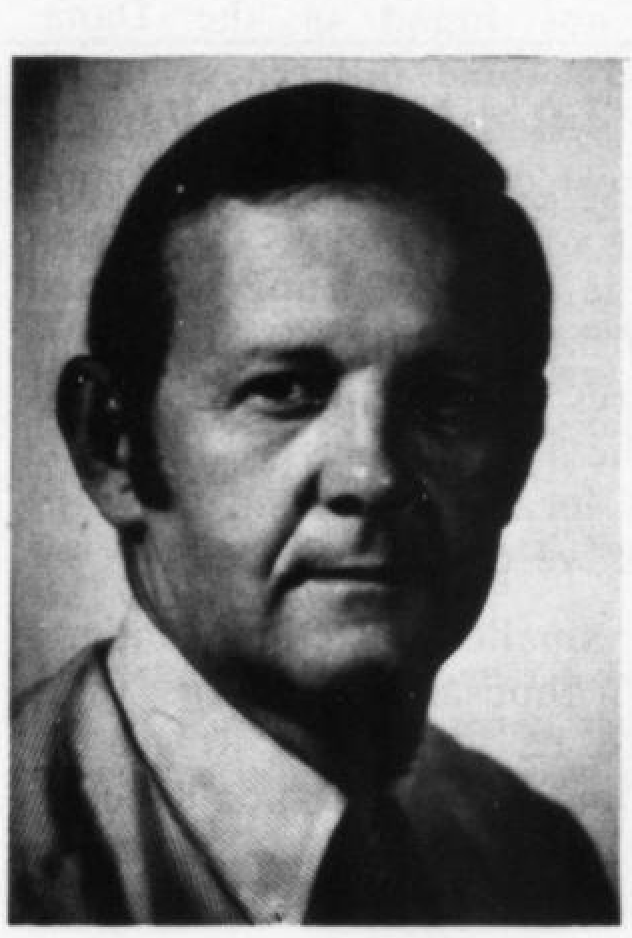


The Museum Record

By Paul E. Desautels

"But if the Dana numbers don't mean anything anymore how can I classify and arrange my collection properly?" Like the proverbial bad penny this plaintive refrain, or something much like it, keeps recurring in my voluminous correspondence with collectors. Actually, the curators of museums often ask themselves similar questions. By default, however, all major mineral museums on this continent continue to use a modified Dana System. This is so primarily because that is what the present generation of curators has inherited in the existing collections and it is too troublesome or costly to change. Our institutional collections have inherited not only the Dana arrangement but, since it was originally patterned on a biological classification, a tendency to leave things that way. It fosters compatability with the biological departments within the museum structure. Whether or not mineral species are best classified in a sort of family—genus—species hierarchy is a moot question. However, to even suggest this in a biologically oriented institution comes close to heresy. There is this problem and several other, often confused and not necessarily related, problems involved in the question of specimen arrangement.

First, there is the Dana situation—referring, of course, to the long delayed updating of the famous and traditional mineral species classification scheme devised by J. D. Dana. Published in 1837 and continued later by E. S. Dana it carried through six editions. The first volume of the seventh edition, authored by C. Palache, H. Berman and C. Frondel, appeared in 1944. Followed by two other volumes, but still lacking coverage of the silicates, much of the book is already out of date. To increase flexibility the species numbering system has also been changed in the seventh edition. In its long history the Dana System became so well established that slavish dependence on the work became commonplace. Even many mineral dealers adopted the practice of printing Dana numbers on their labels. Now, collectors and museums are beginning to find the "Dana" increasingly useless if it is employed as a physical arrangement guide for specimens in their collections. The "Dana," in spite of this, is still the best and most basic species compendium that any serious collector or curator can have. It is a requirement for our libraries. However, it never was intended as anything but a publication for organizing all the known data about all the mineral species. It was not devised as a warehouse coding system.

Minerals are, after all, natural chemical entities with a variety of definitive structures. There is, then, a niceness—*not a rightness*—to arranging them physically according to chemical and structural similarities and dissimilarities. This is the Dana System. But should we really arrange them this way—and why? Larger museums have suddenly begun to examine this question in light of the potential of computers for keeping track of large numbers of specimens. In a nutshell, it now appears that it is much more logical to expect arrangement systems to differ depending on the reasons the collector or curator may have for organizing his specimens.

continued in next column

I remember how impressed I was many years ago to discover that Lou Perloff kept his thousands of superb micromounts in Dana sequence because he was thus forced to memorize the System if he was ever going to find anything. At that time I was arranging my own several thousand micromounts alphabetically by species because I happened to know the alphabet. I rarely had trouble finding anything. And this gets to the crux of the matter! *If* the purpose of arranging minerals is to locate something quickly on demand, as long as there is some economical way to recover what you want, it makes little difference where it is located in relation to all the other specimens. Other purposes may require other arrangements. It seems to me that each collector and each museum would rightly devise a system best suited to the functions of the collection. There is no one single system that can satisfy all. Rigidity in universal arrangement schemes can actually become an impediment to our thinking about species rather than an aid. Somehow, for example, we all tend to think of spinels as a group of multiple oxides. It takes an effort to treat them as aluminates, ferrates, etc. with identical structures.

At the Smithsonian we are rapidly approaching the time when the entire mineral collection will be committed to the computer. The American Museum of Natural History, in New York city, has already begun to work on such a project. Our system has not yet been established. However, it now looks as if we will rely on the computer to tell us just what we have and where it is physically located. If so, perhaps something like a simple arrangement of species alphabetically will suffice. Of course, small modifications, to keep all the pyroxenes or amphiboles or micas together, might be made. Solid solution series, *i.e.* smaltite-chloanthite, might also need to be kept intact. This would make quick visual comparisons possible without skipping all over the collection. By this plan, anyone interested in cronstedtite from Chile can ask the computer what we have of it and where it is located. Of course, this doesn't require any particular arrangement but alphatetization would make it possible to go directly to cronstedtite under the C's without bothering the computer with such simple work.

What we are doing now is somewhat akin to this. In the National Collection all species are arranged in successive tiers of drawers, each tier numbered starting at 1 and going through 140. In the drawers of these tiers, specimens of a species are arranged alphabetically by their geography. The species, of course, by inheritance are arranged by the Dana System. If you should want to look at aragonite crystals from Bohemia (Czechoslovakia) you can go directly to the carbonates—assuming that you know aragonite is a carbonate and assuming you know where carbonates lie in Dana's System. Scanning over the labels on a few tiers of carbonate drawers will bring you to aragonite and then alphabetically to Czechoslovakia. If these assumptions are wrong all is still not lost. In the same room is a card file in which each species in the collection is listed along with its tier number. The card for aragonite in the alphabetical file says it is in tier #48 and there you are. This is our rudimentary computer-like system and it works admirably—as long as the "finder file" is kept up to date. Real computerization will do much more for us, of course. It will be possible to keep track of each individual specimen, research or publication data relating to it and even a history of the uses to which it may have been put. Anyone should be able to find quickly in the collection a chemically analyzed rubidium feldspar with more than 6% rubidium—if we have one. If we don't, the computer can select the closest substitute for us.

Our present system has proved functional even during a period of rapid expansion of the collection over the last fifteen years. There have been some problems. An inordinate amount of labor has gone into distributing thousands of specimens into their appropriate Dana positions. The mental and physical effort may not have been economic. Also, as certain sections have expanded more rapidly than others, massive drawer shifting orgies were necessary. What a blessing that all the drawers are interchangeable!

Another complicated problem has been the accurate placement in the system of all *new* species described following publication of the Dana. Two other compendia have been of invaluable assistance in this. These are ***Mineralogische Tabellen*** by Hugo Strunz and ***Chemical Index of Minerals*** by Max Hey. Both works include many newer species not found in the Dana. There are some differences in all of these systems with that of Strunz being most closely related to Dana, but Hey's Index having the gross advantage for us of being published in English. In our operation, the differences are arbitrarily reconciled, the new species is filed, its physical location noted in the card file, and we proceed as before.

For smaller collections, under a couple of thousand specimens, there seems to be little need to get excited about how they should be arranged. One objective seems as valid as another. Perhaps esthetics alone prompts the arrangement. A collector attempting a species or "Dana" collection might want them so arranged. (It's odd that I've never heard of a "Hey" collector.) If the primary interest is in paragenesis then grouping by mines or mining districts might be best.

It seems to me—unless sheer bulk of the collection requires the most economical organization for the maximum number of uses as is the case with the big museums—there is no one way or no "correct" way to organize specimens. It depends entirely on your own objectives. Not totally unrelated to specimen arrangement, and very pertinent to specimen keeping and care, are the twin problems of cataloging and labeling. These are large enough topics in themselves to be debated in a future column.

MEETINGS & SHOWS

WHO & WHAT	WHEN	WHERE	CONTACT
Spruce Pine Mineral and Gem Festival, 13th Annual Show	**Aug. 4-7**	Harris High School Spruce Pine North Carolina	**Mrs. G. B. Sproles,** Box 354 Spruce Pine North Carolina 28777
Mineralogical Soc. of America, summer mtg. (Pegmatite Phosphate Symposium), jointly with Clay Minerals Soc., ann. mtg., and North American Clay Minerals Conf.	**Aug. 8-12**	Rapid City South Dakota	**D. H. Garske,** S. D. School of Mines, Rapid City South Dakota 57701
San Francisco Gem & Mineral Society, Inc., annual show	**Aug. 14-15**	Hall of Flowers Golden Gate Park San Francisco, Calif.	**Barbara Gray/Clifford J. Krueger,** 270 Morningside Drive San Francisco, California
Amer. Fed. of Min. Societies & Northwest Fed. of Min. Societies, annual show in conjunction with Seattle regional show	**Sept. 3-6**	Seattle Coliseum Seattle, Wash.	**Ed Messerly,** 3017 N.E. 97th. Seattle, Wash. 98115
Conference, Physics & Chemistry of asbestos minerals	**Sept. 6-9**	Louvain University Belgium	**G. Poncelet,** Laboratoire de Physico-Chimie Minerale, Institut des Sciences de la Terre de Croylaan 42, 3030 Heverlee Belgium
Rocky Mountain Federation Show	**Oct. 1-3**	Topeka, Kansas	**R. C. Roderick,** 2106 East 6th. Topeka, Kansas 66607
Baltimore Mineral Society, 15th annual micromount symposium	**Oct. 2-3**	Stemmers Run Junior High School Baltimore, Md.	**H. V. Corbett** 3220 Berkshire Rd. Baltimore, Maryland 21214
Mineralogical Society of Lombardy, 6th Exchange-day of Minerals	**Oct. 23-24**	"Sala della Balla" Sforzesco Castle Milan, Italy	**Daniele Ravagnani** Via Procaccini, 54 20154 Milano (Italy)
Waterford Gem & Mineral Club, annual show "The Wonder of Rocks"	**Oct. 23-24**	Gold Room Oakland University Rochester, Mich.	**Vic Wendler,** 45 W. Drahner St. Oxford, Mich. 48051
Geological Soc. of America and Mineralogical Soc. of America, annual meeting	**Nov. 1-3**	Washington, D.C.	**GSA Headquarters,** Box 1719 Boulder, Colorado 80302
Michigan Mineralogical Society **Greater Detroit Gem & Mineral Show**	**Nov. 5-7**	Detroit Light Guard Armory, Detroit Michigan	**Mrs. Charles Towle** 22114 Allen-A-Dale Birmingham, Michigan 48010
The Mineralogical Society of Southern California, Annual Mineral Show	**Nov. 6-7**	Pasadena City College, Pasadena California	**Bob Pederson,** 645 Maryanna Lane Monrovia, California 91016
1972			
Tucson Gem & Mineral Society, 18th Annual Show	**Feb. 11-13**	Tucson Community Center Tucson, Arizona	**Joe D. Kreps,** 1402 W. Ajo Way =271, Tucson, Arizona
Geological Society of America *Northeast Section,* ann. mtg.	**Mar. 9-11**	Buffalo, New York	**E. J. Buehler,** Dept. of Geol. Sci., State University of New York Buffalo, N.Y. 14207
Geological Society of America, *South Eastern Section,* annual meeting	**Apr. 15-17**	Tuscaloosa, Alabama	**T. A. Simpson,** Geological Survey of Alabama, Drawer O University, Ala. 35486
South Central Fed. of Mineral Societies Convention and Show	**May 5-7**	New Convention Center Wace, Texas	**Otto Schlemeyer** 1913 Mountainview Drive Waco, Texas 76710
Mineralogical Society of Arizona (& Rocky Mountain Federation), 1st annual show "Gems of the Desert"	**Jun. 23-25**	Veterans Memorial Coliseum, Arizona State Fairgrounds Phoenix, Ariz.	**Perry Stufflebeam,** 3139 W. Holly Phoenix, Arizona 85009
Amer. Fed. of Min. Societies & Calif. Fed. of Min. Societies, Annual show "Fantasy of Gems"	**June 29-July 2**	Anaheim Convention Center Anaheim, California	**Don J. Blood,** P. O. Box 3055 Orange, California 92665
Geological Soc. of America and Mineralogical Soc. of America, annual meeting	**Nov. 13-15**	Minneapolis, Minn.	**GSA Headquarters,** Box 1719 Boulder, Colorado 80302
1973			
Amer. Fed. of Min. Societies & Eastern Fed. of Min. Societies show	**June 28-July 1**	Charlotte Merchandise Mart, Charlotte North Carolina	**Al Lewis,** P. O. Box 712 Charlotte, N.C. 28201

Ytterby, Sweden: a classic mineral locality

By **Brian Mason,** *Smithsonian Institution,* Washington, D.C.

"The $64,000 Question" has passed into limbo along with many less memorable quiz shows, without ever having asked the question I once proposed: what locality has provided the names for four of the chemical elements? The answer, of course, is Ytterby, from which is derived the names (and the elements themselves) ytterbium, yttrium, terbium, and erbium. Several other elements were first discovered in minerals from this place.

Ytterby (trans. "outer village") is a small hamlet on Resarö, an island in the approaches to Stockholm from the Baltic Sea. *(Fig. 1).* Its place in the history of mineralogy and chemistry may have resulted from a fortunate coincidence of several chance circumstances —a mineral-rich pegmatite worked over a long period of time for ceramic raw materials (quartz and feldspar), close to a large city with an outstanding tradition for mineralogical and chemical research.

The Ytterby deposit is a typical granite pegmatite —a vein-like body of coarsely crystallized quartz and feldspar. It was well exposed on the coastal cliffs of Resarö and hence attracted early attention as a potential mine. In addition, the material could readily be delivered directly into ships for easy and cheap transportation. Mining apparently began around 1780, and continued well into the present century. Production during the period 1864-1908 amounted to 17,536 tons of quartz, 3019 tons of oligoclase, and 25,453 tons of microcline and microcline perthite. The pegmatite body consisted of a series of interconnecting steeply-dipping lenses, which were mined to a depth of some 500 feet, and a large adit was excavated at a depth of 180 feet.

When I first visited Ytterby in 1940 work had already ceased for some years, and the mine was partly filled with water. However, there were very extensive dumps, and large blocks of pegmatite had been used in building walls along the foreshore and also in the foundations of the local houses. Collecting was always good, even on my last visit there with Professor Clifford Frondel in 1951 *(Fig. 2).* Since then, however, the Swedish authorities have taken over the old mine and converted it into an oil storage depot—surely a mean and melancholy fate! The mine and part of the surrounding area are now fenced off and inaccessible, but collecting may still be possible in the dump material scattered along the shore.

The minerals that have been found at Ytterby are listed in Table 1. In spite of intensive collecting over

Fig. 1. Map showing location of Ytterby, Sweden.

Table 1
Minerals of the Ytterby pegmatite

Major	
Quartz	SiO_2
Microcline	$(K, Na) AlSi_3O_8$
Oligoclase	$(Na, Ca) (Al, Si)_4O_8$
Biotite	$K(Mg, Fe)_3 (AlSi_3O_{10}) (OH)_2$
Chlorite	$(Mg, Fe)_5Al(AlSi_3O_{10})(OH)_8$
Muscovite	$KAl_2(AlSi_3O_{10})(OH)_2$
Common	
Gadolinite	$YFeBe_2Si_2O_{10}$
Yttrotantalite	$Y (Ta, Nb, Fe)_2O_6$
Fergusonite	$Y(Nb, Ta)O_4$
Allanite	$(Ca, Y)_2(Al, Fe, Mg)_3Si_3O_{12}(OH)$
Beryl	$Be_3Al_2Si_6O_{18}$
Spessartine	$Mn_3Al_2Si_3O_{12}$
Magnetite	Fe_3O_4
Pyrrhotite	Fe_7S_8
Pyrite	FeS_2
Molybdenite	MoS_2
Accessory	
Xenotime	YPO_4
Tengerite	$CaY_3(OH)_3(CO_3)_4 \cdot 3H_2O$ (?)
Chrysoberyl	$BeAl_2O_4$
Calcite	$CaCO_3$
Fluorite	CaF_2
Apatite	$Ca_5(PO_4)_3F$
Zircon	$ZrSiO_4$
Cordierite	$(Mg, Fe)_2Al_4Si_5O_{18}$
Tourmaline	$NaFe_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

many years, this list may still be incomplete: on a visit in 1949 I found a specimen of chrysoberyl, which had not previously been recognized at this place (nor anywhere else in Sweden, apparently). The fame of the pegmatite rests on the rare earth or lanthanide minerals, of which the most abundant are gadolinite, yttrotantalite, fergusonite, and allanite. These are commonly found as rough crystals attached to large plates of biotite, but also occur within large masses of feldspar.

Scientific research on Ytterby minerals began in 1788, when B. R. Geijer, at that time director of the Rörstrand porcelain factory, described as a "black zeolite" the mineral eventually named gadolinite by Klaproth in 1800 (like many zeolites, gadolinite dissolves in acid with the separation of gelantinous silica). Geijer noted the high density (which he determined as 4.223) and suggested it might indicate the presence of barium or tungsten, two of the few heavy elements that were then recognized. In 1794 Professor Gadolin of the University of Abo in Finland (at that time a Swedish province) analysed the mineral and determined the presence of about 38 percent of a previously unknown "earth" or oxide. Three years later A. G. Ekeberg at the University of Upsala confirmed Gadolin's results and called the new oxide yttria, and the element has thus become known as yttrium. However, the material extracted as yttria from the Ytterby gadolinite contains all the lanthanide elements, and the following century saw a long series of investigations which fractionated this material into a successive series of new elements *(Table 2)*.

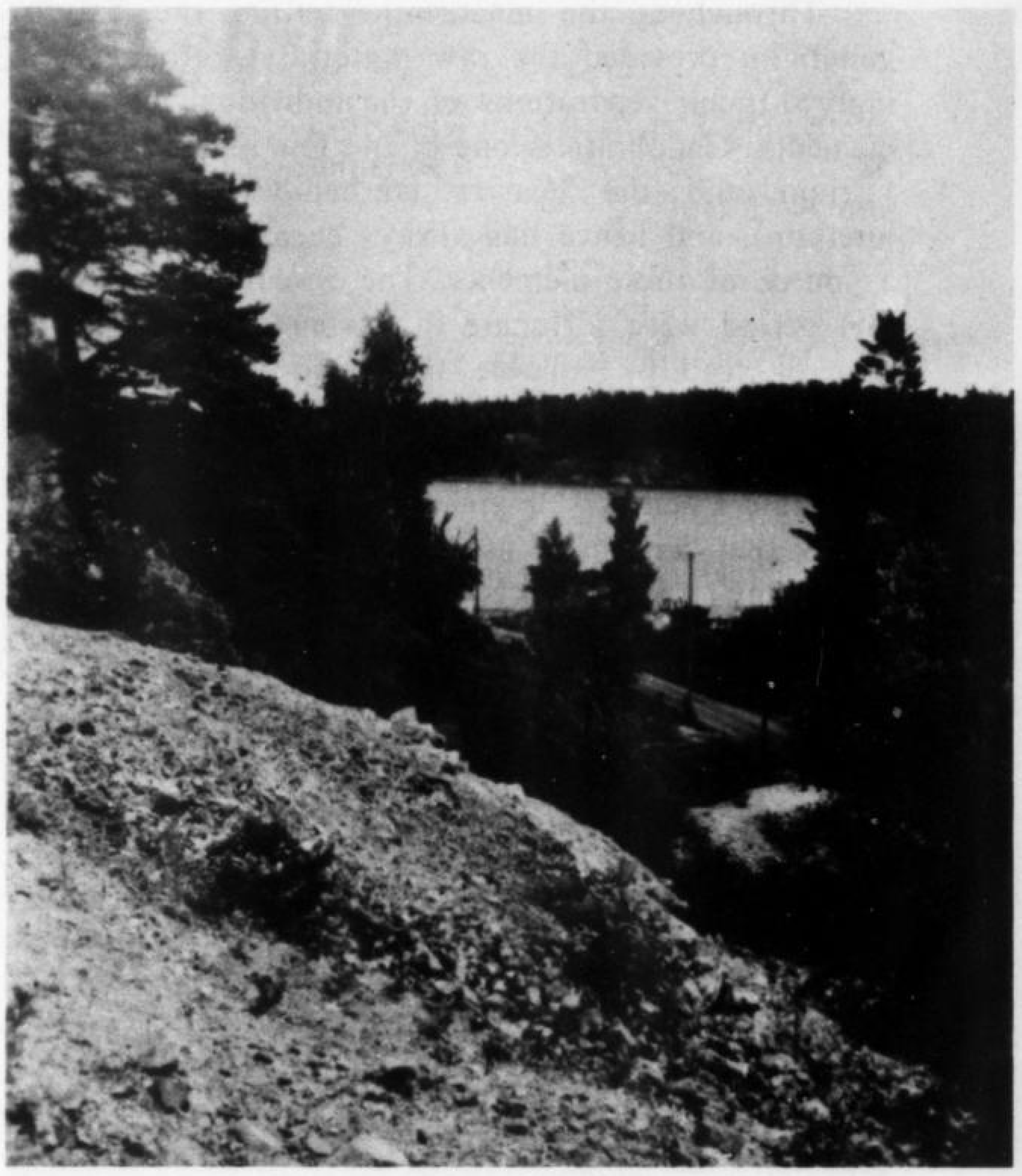
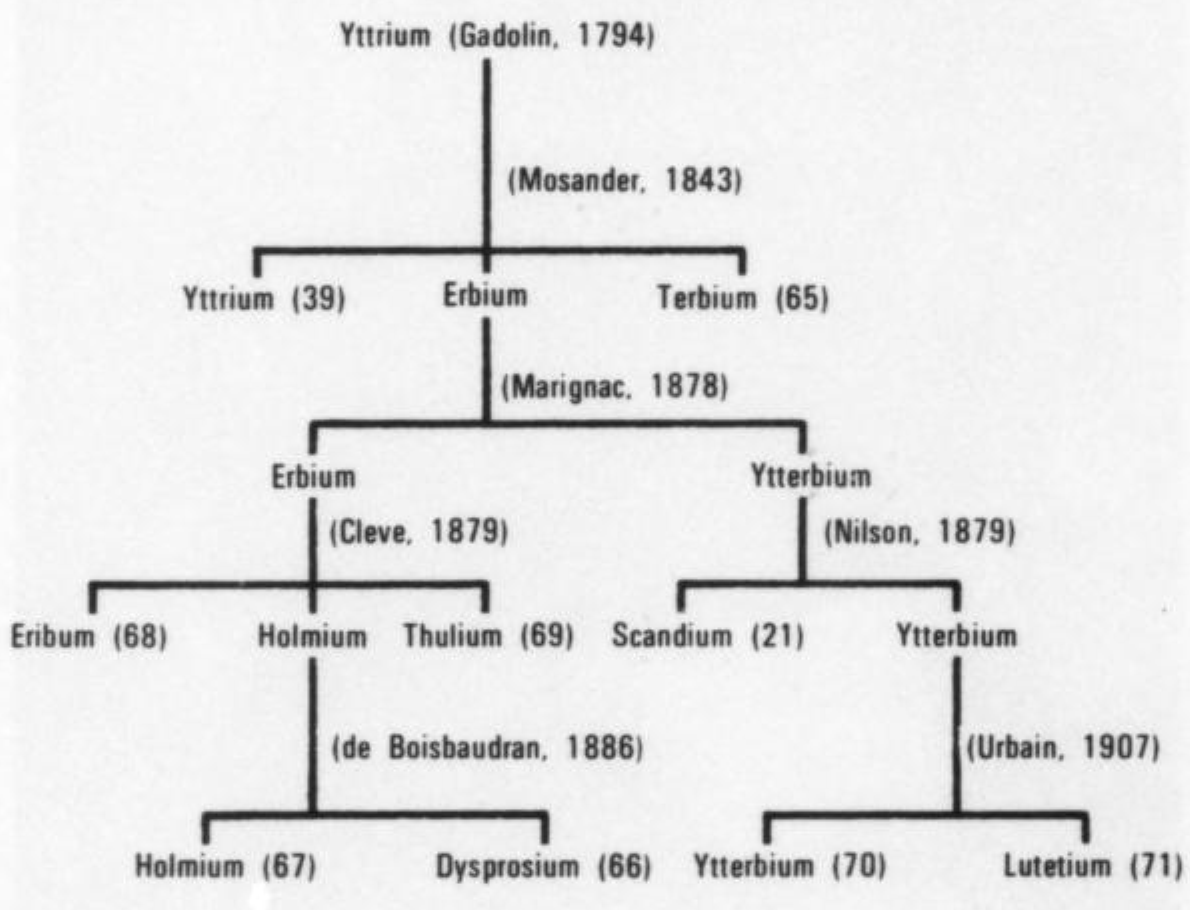


Fig. 2. Part of the dump of the Ytterby mine in 1951.

Table 2
The sequence of separation of the lanthanide elements (and scandium) from gadolinite; figures in parentheses are atomic numbers.



Ekeberg continued his researches on Ytterby minerals, and in 1802 he announced the discovery of the element tantalum in a mineral which he named yttrotantalite, from its composition. At that time two varieties of yttrotantalite were recognized at Ytterby, yellow and black. The "yellow yttrotantalite" was later (in 1826) identified as a distinct mineral, fergusonite.

Throughout the nineteenth century the Ytterby gadolinite provided the raw material for the exceedingly difficult separations of the individual lanthanide elements. Gadolinite is one of the few minerals rich in yttrium and the heavier lanthanides (terbium to lutetium), and hence has always been sought after as a source of these elements. The Swedish chemists of this period were fortunate in having a supply of this mineral readily available from the working of the Ytterby pegmatite. I recall from my student days in the University of Stockholm seeing in the Institute for Inorganic Chemistry a great pile of large evaporating basins that had been used in the tedious and time-consuming fractional crystallizations that were used to separate the individual elements. Today this is much more readily achieved by ion-exchange columns. It is hard to realize the magnitude of the problem facing the chemists of last century in investigating these elements. They had no way of knowing how many different elements actually existed. This was solved first by the discovery of regularities in the X-ray spectra of the elements by H. G. J. Moseley in 1913. This revealed that there are 15 elements in the lanthanide group, from lanthanum (57) to lutetium (71), of which 14 were then known; the missing one (61) has proved to be a short-lived radioactive element, which has been named promethium, and has not been found in any natural material on earth.

Fig. 3. Gadolinite, Ytterby, Sweden. **Photo by Joel E. Arem.**

Because of the extreme difficulty of separating the individual lanthanide elements by classical techniques of chemical analysis, most of the analyses of gadolinite simply report them all together as Y_2O_3, sometimes with a determination of the molecular weight, which gives some indication of the composition (pure Y_2O_3 has a molecular weight of 226, and Y_2O_3 extracted from gadolinite usually has a molecular weight of 250-260, showing the presence of the heavier lanthanides). I have not been able to find a complete analysis of the Ytterby gadolinite in the literature. A published analysis of a gadolinite from Hitterö, Norway gives the following percentages of yttrium and rare earth oxides: Y_2O_3 29.3, La_2O_3 0.24, Ce_2O_3 0.88, Pr_2O_3 0.32, Nd_2O_3 2.19, Sm_2O_3 1.66, Gd_2O_3 3.35, Tb_2O_3 0.65, Dy_2O_3 4.02, Ho_2O_3 0.55, Er_2O_3 2.57, Tm_2O_3 0.40, Yb_2O_3 4.64, Lu_2O_3 0.46. This is probably fairly representative of the relative abundances of these elements: yttrium is by far the most abundant, and within the lanthanide group the even-numbered elements are uniformly more abundant, usually by a factor of about five to ten, than the odd-numbered elements on either side (the Oddo-Harkins rule).

It may be noted that scandium, the element above yttrium in the periodic table, was discovered in gadolinite by Nilson in 1879, although this mineral only contains about 0.1 percent of the element. Curiously enough, the element gadolinium was not found originally in gadolinite; it was isolated from an American samarskite by the Swiss chemist Marignac in 1880, and given the name gadolinium by the French chemist Lecoq de Boisbaudran in 1886, presumably in honor of Gadolin.

A visit to Ytterby is an easy and pleasant excursion from Stockholm. When I lived in Stockholm one took a steamer from the city to Vaxholm, where one changed to a small launch for the short ride to the landing stage at Ytterby, the whole trip taking about two hours. There is now a bridge from the mainland to Resarö, and it is possible to drive there from Stockholm in about an hour. Even if the mineral collecting may not be what it used to be, Ytterby is a delightful spot on a warm summer day, and one can well conjure up the shades of long-departed chemists and mineralogists who have collected at this spot over almost two centuries.

The literature on Ytterby minerals is extensive but very widely scattered through many journals. The best general account is in German by I. Nordenskjöld, "Der Pegmatit von Ytterby," published in vol. 9 (1910) of the ***Bulletin of the Geological Institution of the University of Upsala.*** For the story of the discovery of the lanthanide elements I recommend ***Discovery of the Elements,*** a book by M. E. Weeks, published by the ***Journal of Chemical Education.***

The Record Bookshelf

A Guide to the Minerals of Switzerland,* by *Max Weibel, John Wiley & Sons, Interscience, New York and London, 1966, 123 pp., ($6.50) (Also available in German, *Die Mineralien der Schweiz, Ein mineralogischer Führer,* published by Birkhäuser Verlag, Basel and Stuttgart)

The minerals of Switzerland are among the most spectacular and distinctive in the world. Few mineral collectors, however, have firsthand knowledge of the Alpine cleft deposits, the mineralogy of the famous Binnatal and other Swiss occurrences, or the geologic setting of these localities. Weibel's compact and highly informative book fills this information gap.

The plan of the book is ideal for a clear understanding of the occurrence of Swiss minerals. Various types of mineral parageneses are clearly related to regional geologic and lithologic settings. Much information is summarized in well-organized tables. Such tabulation is a great help in keeping track of, for example, the 96 species occurring in cleft deposits listed by Weibel. Ore minerals of the Alps are listed separately. The bulk of the text is devoted to descriptions of individual species, with notes as to composition, habit, occurrence, associations and size. These descriptions are helpful in visualizing many of the deposits, but are incomplete in that all known Swiss occurrences for given species are not tabulated. The 71 color plates are all of excellent quality, and are enormously helpful in identifications.

Regional occurrence descriptions are discussed in some detail, in the style of a guided tour through various mountain regions. Sketch maps are included to enable the reader to locate the occurrences described. The text gives an excellent picture of past and present mining operations as well as mineral associations. A final section of the book, on quarries and sources of Swiss minerals, museums and field trips adds to the overall usefulness of this book as a traveler's guide.

Weibel's emphasis on the rocks and overall paragenesis of Swiss mineral occurrences is invaluable. Writers of field guides to any area would be wise to study the format and style of Weibel's book, for it should be considered a model for guidebooks of this type. ■

Joel E. Arem

Connecticut Mines and Minerals,* by *John Hiller, Shelton, Conn. (privately published), 1971, 68 pp., 55 maps, (paperback), $3.00
(Order from: Hiller's Crystal Shop, 3 Peters Ln., Shelton, Conn. 06484)

The number of mineral-locality collector's guidebooks currently available is quite large, and the number is growing yearly. Little justification could be found for proliferating this type of publication unless a significant contribution could be made to the locality information already accessable. Hiller's book does not reveal the existence of long-hidden collecting spots, but it does update current information and present it in a thoughtful way.

The format of *Connecticut Mines and Minerals* is not original or new. The information pertinent to each locality (about 50 included) is simply listed, as follows: town, locality, minerals, permission needed, fees, ownership, tools needed, cleaning tips, misc. data. A very rough sketch map for each locality seems adequate for finding it, but this should probably be accompanied by a standard road map. All the minerals to be found at a given spot are not listed, but rather the chief mineralization or the species the collector is likely to find. This is especially important, in light of the legions of collectors who follow guidebooks to apparant bonanzas, only to be severely disappointed. The rock type at each locality is not given, perhaps the most striking omission to be found in the book. The tips on cleaning and miscellaneous data seem extremely useful: Hiller makes sure to remind the collector to close all gates and observe safety precautions—a touch not to be found in most guidebooks. In fact, Hiller's book is, in spite of its simplicity, far more useful than many of the rock and gem guides currently available. This guide is recommended for any collector especially interested in Connecticut minerals. ■

Joel E. Arem

Mineral Collecting in Pennsylvania,* by *Davis M. Lapham* and *Alan R. Geyer, Bulletin G-33, Pennsylvania Geological Survey, 1969, 164 pp., (paperback), $.50
(Order from the Pennsylvania Bureau of Publications, P.O. Box 1365, Harrisburg, Pa. 17125, and make check payable to the Commonwealth of Pennsylvania)

This excellent guide to mineral collecting localities in Pennsylvania could profitably serve as a model for all such field books. Though relatively few of the numerous collecting areas in the state are discussed, those mentioned include several new localities and all the sites mentioned are productive. The format of the guide is its chief asset, however. Each locality is exactly pinpointed on a reproduction of the pertinent topographic map of Pennsylvania. This feature will be well received by any collector who has spent half a day searching for a locality on the basis of vague or not sufficiently detailed information.

Several other features of the guide are of interest. A general introduction to the use of topographic maps is presented, some terms relating to minerals and collecting in general are defined, and several pages are given to a discussion of mineral associations and the use of typical assemblages in identifying minerals. This latter is a basic principle that most collectors seem to underemphasize, much to their misfortune. A short paragraph on the geology is included with the description of each locality, as well as one or more references for more details.

The very low cost of this Bulletin (and, happily, most state and U.S. Government publications) makes its acquisition rather painless to one's pocketbook. But the information contained in it and the style of presentation would make the book attractive even at double its actual cost. ■

Joel E. Arem

***Crystallography and Crystal Chemistry**, by F. Donald Bloss. Holt, Rinehart and Winston, New York, 1971, 545 pp. ($15.95).*

The excellence of this latest work by F. Donald Bloss will come as no surprise to those already familiar with his superb *Introduction to the Methods of Optical Crystallography* (see *Min. Record*, **1**, 129). The circumstances involving marketability and timing of publication are the same for both books: both have been published at a time when several good texts were already currently available in their respective subject areas. It is a tribute to Prof. Bloss that his optical crystallography book immediately rose to a top position among works in its field. The current offering, *Crystallography and Crystal Chemistry*, should follow the same pattern.

As with the optical book, *Crystallography and Crystal Chemistry* is noteworthy in two respects: clarity of presentation of text, and masterful and ingenious drawings and figures. The contents of the latest work are not much different from those to be found in numerous other texts. No one book can cover all the various aspects of crystallography and related areas of materials science, mineralogy, X-ray diffraction and physical chemistry. The reader must therefore carefully select the book that contains information most relevant to his work and/or interests. Bloss has included a range of subjects that will be of interest to mineralogists, ceramists, chemists, solid-state physicists and metallurgists. This selection is aimed at the student just beginning to study crystallography; but it is an excellent overview for the mineral collector who may not realize exactly how wide a diversity of disciplines uses crystallography as a working tool, and how many of these studies relate directly to minerals.

Bloss treats external symmetry of crystals first, rather than internal symmetry; this "debatable decision", as he puts it, assumes that operations of external symmetry are simpler and grasped more easily by the beginning student. The first 150 pages of the book cover crystal classes, crystal systems and axes, symmetry, nomenclature, forms, lattices and projections. The chapter on projections is detailed and rigorous, and will prepare the student adequately for discussions of graphical representation of crystallographic measurements. Such background and training are invaluable to any serious student of earth sciences. The drawings and analogies in the first few chapters are especially lucid. Concepts of plane, axial and inversion symmetry are illustrated by a football field, a world globe, and a room containing a table and chair (the inversion operation produces duplicates of these that hang from the ceiling). Rotation and inversion axes are illustrated by showing the positions of a human hand after rotations and reflections. The text is extremely readable, almost conversational, and tends to be wordy where more words seem necessary to explain a difficult point. The presentation of space group symmetry operations (glide planes, screw axes) is especially well illustrated. The chapters on crystal chemistry and structural variations, composition and stability will be useful to the college student as well as to the serious mineral collector.

Concepts of crystal chemistry and structure are comprehensively and clearly explained. Parts of Chapter 10, on structural variations, composition and stability seem, to this reviewer, more compressed and difficult than the rest of the book, but the material covered is unquestionably relevant and worthy of inclusion. Physical properties are discussed in a way that stresses their dependence on symmetry. For those readers who are mathematically inclined and seek a rigorous approach to crystallography, a section on tensors should prove challenging. The final chapters, on crystals and light and X-ray diffraction, adequately round out the scope and coverage of the text.

For both the academic and the hobby-oriented student, *Crystallography and Crystal Chemistry* will prove useful and illuminating. The clarity of presentation, scope and depth of topical coverage, superb illustrations and relatively low cost should set the book high on the reading list of anyone interested in crystallography and crystal chemistry. ■

Reviews By Joel E. Arem

New Minerals from Mont St. Hilaire, Quebec

By Ted Agos, Dave Richerson, and A. J. Regis

Over 100 different minerals have been reported from Mont St. Hilaire, Quebec. Many of the rare species have been described in *Canadian Mineralogist*. A complete list of the minerals identified from St. Hilaire was compiled by G. Y. Chao, D. C. Harris, A. W. Hounslow, J. A. Mandarino, and G. Perrault and appeared in *Canadian Mineralogist* Vol. 9 part 1, 1967.

During the past two years, extensive x-ray diffraction studies by the authors on material collected during the past four years (much of it from regions of the quarries which no longer exist) have revealed a number of previously unreported species from Mont St. Hilaire. These are listed in Table I.

Several other minerals have also been collected at St. Hilaire, but require special discussion. The first is apparently a pseudomorph of ancylite $4Ce(OH)CO_3\cdot 3SrCO_3\cdot 3H_2O$ and bastnasite $CeFCO_3$ after parisite $CaCe_2(CO_3)_3F_2$. The crystals generally consist of a white to gray hexagonal, prismatic shell with shallow pyramid faces on the termination. This shell is generally bastnasite. Inside the hollow shell are elongated gray to pink crystals of ancylite.

Another specimen collected at St. Hilaire contained stibnite, gudmundite and senarmontite. This sample was obviously from Lac Nicolet, Quebec, an antimony deposit 80 miles northeast of St. Hilaire. Evidently, someone had collected this sample at Lac Nicolet before collecting at St. Hilaire and inadvertently left it at St. Hilaire. This points out one of the problems of studying the minerals of a specific deposit: one must be very careful during collecting to be absolutely certain where the specimens originated. Loose specimens should be carefully marked and kept separately, and later examined for features which link it to the host formation.

Still another specimen is probably a valid discovery from St. Hilaire. It consists of tiny acicular pyromorphite $Pb_4(PbCl)(PO_4)_3$ crystals on calcite and was found in a highly altered sulfide zone. The question arose as to whether this might also have been an artifact from some other locality, since only one sample had been collected. A study of pyromorphite from eastern U.S. localities (Loudville, Mass.; Rhode Island; and Phoenixville, Penna.) failed to turn up anything similar to the sample from Mont St. Hilaire.

The chemistry of pyromorphite does not preclude its occurrence at St. Hilaire since there are other lead and phosphate minerals present. Also, the presence of anglesite and malachite indicates that suitable alteration conditions have been present.

Undoubtedly there are many other minerals which can be added to the growing list of St. Hilaire minerals. However, since many will occur only as micro crystals, sophisticated instrumental analysis will be required for their proper identification.

Acknowledgements.—The authors are grateful to J. Bradley, Gil George, and Peg Marble who generously supplied samples for study.

Table I

Mineral Name	Composition	Associations	Description
Anglesite	$PbSO_4$	Minerals of altered sulfide-containing zones.	White to cream-colored coatings on galena crystals.
Brockite	Sr, Ca, Ba, Th, Y Carbonate Phosphate, Hydrate	Ancylite, aegirine, albite catapleiite, genthelvite, sphalerite, galena.	Yellowish micro crystals occurring as flat, etched or rounded plates.
Fluoredenite	$NaCa_2(FeMg), (Si_7AlO_{22})$ $(OH, F)_2$	Aegirine and fibrous white talc. Quartz	Zoned, doubly terminated green to blue-green micro crystals imbedded in aggregate of aegirine needles or talc or in open vugs.
Hedenbergite Var. Salite	$Ca\ (Fe, Mg)\ Si_2O_6$	Albite, crocidolite	Transparent, yellow, elongated prismatic micro crystals in very vuggy albite
Heikolite	$(Na, Ca)_2\ (Mg, Fe, Al)_5$ $Si_8O_{22}(OH)_2$	Galena, sphalerite, strontian apatite, aegirine, pyrophanite, red biotite.	Elongated, dark green crystals resembling actinolite. Distinct terminations, rather than acicular.
Hibschite	$Ca_3Al_2Si_2O_8(OH)_4$	Pectolite, calcite, molybdenite	Octahedral micro crystals on pectolite—easily mistaken for apophyllite
Lessingite	Ca, Rare Earth, Si, Al	Zircon, analcime (yellow)	Resin-brown tetragonal shaped crystals with pyramidal terminations. Resemble simple forms of vesuvianite or zircon.
Malachite	$CuCO_3 \cdot Cu(OH)_2$	Chalcopyrite, calcite and other altered sulfide zone minerals.	Very small green acicular crystals coating calcite and chalcopyrite.
Minnesotaite	$(Fe, Mg)\ AlSi_4O_{10}(OH)_3$	Limonite pseudo after siderite, albite, rutile, burbankite. Highly altered zone.	Light green fibrous aggregates
Ripidolite	(Fe, Mg, Al, Si), (Al, O, OH)	Red rhodochrosite, altered aegirine	Replacement of aegirine
Talc	$Mg_3Si_4O_{10}(OH)_2$	Fluor-edenite, aegirine	Loose aggregates of white fibers
Tobermorite	$Ca_5Si_6O_{17} \cdot 5H_2O$	Albite, aegirine, mangan-neptunite	White fibrous bundles.
Strontian-apatite	$Sr_5(OH)(PO_4)_3$	Galena, heikolite, sphalerite, calcite, red biotite	Very small elongated, hexagonal, prismatic crystals with pinacoid terminations, colorless.

Rhodochrosite Crystal Localities in the West

(Continued from page 110)

Park County	
Sweet Home mine, Buckskin Gulch, Southeast of the Red Amphitheater near Alma	Superb, bright red, gemmy, rhombo hedra up to 1-1/2 inches long. Associated with pink, blue, and green octahedral fluorite crystals, pyrite, huebnerite, and jamesonite.
Tanner Boy mine, Southwest side of Buckskin Gulch	Similar to Sweet Home mine.
Russia mine, East face of Mt. Lincoln at altitude of nearly 14,000 feet.	Similar to Sweet Home mine.
Saguache County	
Eagle mine, southern part of Bonanza mining district.	Pale pink scalenohedra with green fluorite to deep pink opaque rhombohedra with slight twist. Often with small pyrargyrite crystals perched on cyrstals of rhodochrosite.
Express mine	”
Rawley mine, northern part of Bonanza mining district	Pale pink scalenohedra of rhodochrosite with manganocalcite and manganosiderite.
San Juan County	
American Tunnel mine Gladstone	Fine pink scalenohedra to deep red rhombohedra up to 2 inches on an edge and scattered on white drusy quartz, galena, sphalerite, or rhodonite. Rarely with free gold.
Sunnyside mine, Eureka Gulch	”
Alaska mine, Head of Poughkeepsie Gulch	”
Titusville mine, Kendall Mt.	”
San Miguel County	
Smuggler mine, Telluride	Small red rhombohedra with quartz and sphalerite.
Summit County	
Queen of the West mine, Argentine Pass	Small red rhombohedra line vugs in massive alabandite.

NOTICE

With each issue we receive many letters just before mailing time asking "What has happened to the magazine?" Many readers do not realize that we are managing to bring the Record to them with bi-monthly frequency, even if we are nearly two months behind the calendar. Therefore, we ask that you not become alarmed until at least two months have gone by since you received your last issue. We are struggling to gain on the calendar but thus far have been able only to avoid falling behind even more. We hope that we will be able to pick up at least one week with each issue until we reach the point where the Jan.-Feb. issue, for example, will arrive near the end of February. Please be patient, the delay is even more agonizing to us and we are doing all we can to correct it.

What's New in Minerals *(Continued from page 129)*

any locality where amazonite has been found.

The other observation by Gaines was that dravite crystals from Yinnietharra, Australia do not appear hemimorphic (the dominant form on either end of the crystal is not the same if hemimorphic) as we all know tourmaline crystals should be. As a followup I examined dravites from other localities and found that those from Prevali, Carinthia, Austria also do not appear hemimorphic. Interestingly these two dravites are nearly identical in color—cinnamon brown—and both are embedded in a light-colored mica.

State of the Art—Part II *(Continued from page 122)*

to use and more convenient than single crystal techniques, as well as requiring less expensive equipment, they are justly treated independently, and will constitute Part III of *State of the Art—X-Ray Crystallography.*

The Need for Specific Locality Data

A continuing study of references in current literature to mineral occurrences in California has emphasized a need for more careful identification of locality in some geology-mineralogy studies. Two examples may suffice.

A recent report in a professional journal described an interesting deposition along "Birch Creek in Inyo National Forest, California." There are five Birch Creeks in Inyo National Forest. It was finally possible, by a study of quadrangle maps, to identify the area of study. It would seem that description of the section, township, range, and meridian location of the study area would have improved the report.

A second article in a professional journal described an interesting mineral occurrence at the "head of Spade Spring Canyon" in Los Angeles County, California. There is a Spade Canyon and a Spring Canyon but there is no Spade Spring Canyon in Los Angeles County. The reported mineral occurrence is in an area at the head of both canyons. Again, identification of the area by the available topographic symbols would have improved the report.

H. Earl Pemberton
Mineral Research Society of California

The Hirsch Collection

A news release about the sale of the Hirsch mineral collection has been dutifully printed by nearly every hobbyists' magazine in the U.S. The collection is described in the release as "One of the finest private mineral collections in the United States," "best in the West," "extraordinary," "world famous." In fact, it is none of these. Knowledgeable mineralogists who have seen it say it is not deserving of these accolades; it is a second rate collection at best; and, although large in number of specimens, it would never have been included in a list of significant mineral collections of the United States. It is nice to get another point of view.

Greater Detroit Gem & Mineral Show

NOVEMBER 5,6,7 - 1971

Detroit Light Guard Armory—4400 East 8 Mile Road, Detroit
Friday 6 to 10 P.M., Saturday—*'CANADA DAY'*—10 A.M. to 10 P.M.,
Sunday 10 A.M. to 6 P.M.

Host—*Michigan Mineralogical Society* in cooperation with
Family Lapidary Club, Great Lakes Rock Club, Michigan Lapidary Society,
Mt. Clemens Gem & Mineral Club and Rock Exchange Club

Principal Events

Friday 8 P.M.—*Mines & Minerals of the Keweenaw*
Jean Peterman Kemp—Asst. Curator, Seaman Mineral Museum
and Bob Seasor—Resident Geologist, White Pine Copper Co.

Saturday 1:30 P.M. *2nd Annual MMS Mineral Symposium*
'The Role of the Amateur in Professional Mineralogy'
Dr. Mandarino, Moderator—Panel Members—Dr. Robert I. Gait,
Prof. D. H. Gorman, Prof. Guy Perrault, John S. White, Jr.

Saturday 8:00 P.M. Canada Day Feature
'Mineral Occurrences and Collecting in Ontario'
Dr. J. A. Mandarino, Curator of Mineralogy, Royal Ontario Museum

Sunday 1:30 P.M.—*'Rare Gems of the Midwest'*
June Culp Zeitner, Contributing Editor, The Lapidary Journal

Sunday 3:30 P.M.—*'6,000 Miles in Mexico'*
Paul Seel, President, American Federation of Mineralogical Societies

* *

For Programs, Information, Advance Tickets, Exhibit Applications, write:
Jeanne Towle, 22114 Allen-A-Dale, Birmingham, Mich. 48010

GIANT TOPAZ CRYSTALS from Minas Gerais Brazil on display in the Gem Hall of the Smithsonial Institution. The larger of the two crystals is nearly two feet high and it weighs 111 pounds, the smaller only 70 pounds. This pair of extraordinary crystals was brought to the U.S. to be cut for industrial use. They have been loaned to the Smithsonian by Dr. and Mrs. S. Andrew Kulin.

Photograph courtesy Smithsonian Institution.