the Mineralogical Record

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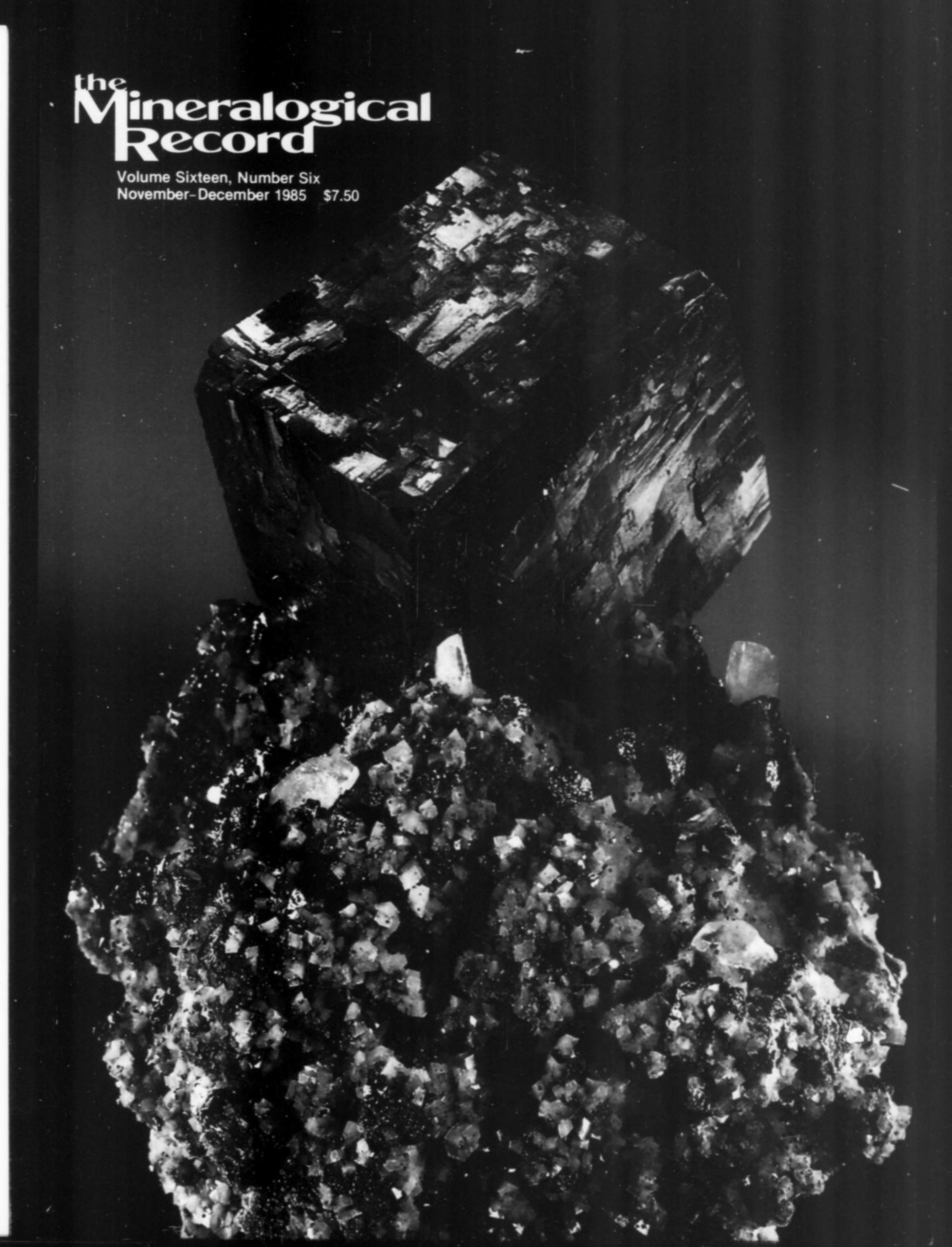

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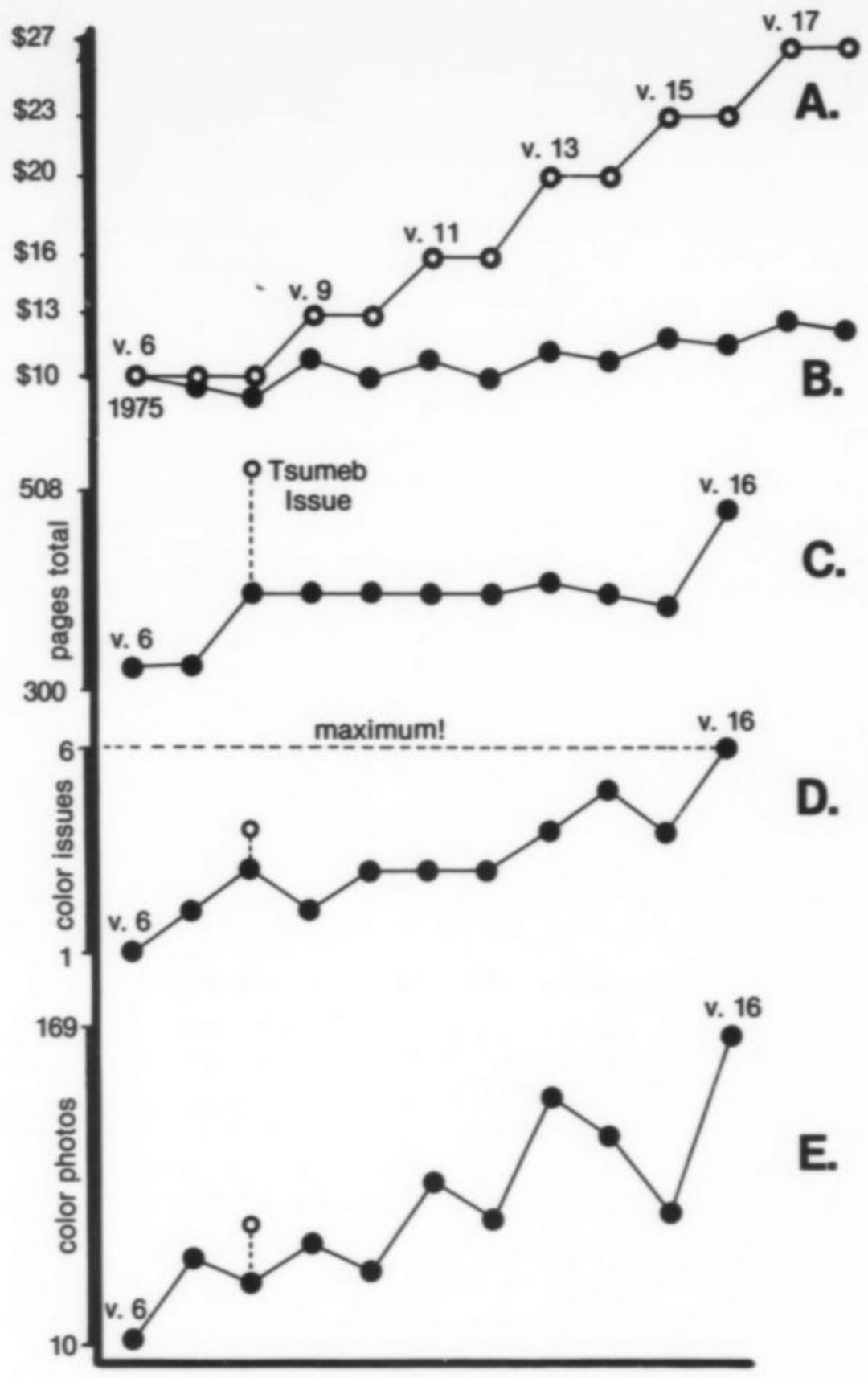
COVER: GALENA, 5 x 5.3 x 6 cm, on matrix with dolomite and chalcopyrite, from the Sweetwater mine, Ellington, Reynolds County, Missouri. Collection of Maudine and Bob Sullivan; photo by Harold and Erica Van Pelt © 1985.

notes from the EDITOR



A LOOK BACK

Every once in a while it's a good idea to take a broad look back at the progress of the *Mineralogical Record*. I do this primarily for the edification of our Board of Directors, as most publishers do (via internal reports). But I also find that our readers take a keen interest in such matters, and like to review the facts for themselves. This seems like a particularly appropriate time, considering that our biannual subscription price increase just took place again. Readers may understandably wonder, at price-increase time, if they are still getting their money's worth like they used to.

Two questions naturally arise: (1) Has the price of a subscription risen faster than the inflation rate? In other words, is the price actually higher in terms of real purchasing power than it used to be? And, (2) has the magazine itself diminished in any way, like the shrinking ten-cent candy bar? To answer these questions I direct the reader's attention to the accompanying graphs.

The top graph (A) shows how our subscription price has increased regularly over the years since 1975. The graph below it, however, shows the price converted to constant-value 1975 dollars, and it can be seen that this has held relatively constant.

Bear in mind that, although our readers certainly would not want to be overcharged, they should want even less to be *under*charged because that would cause us to go out of business in a short time. It is important that we at least keep even with inflation if we are to survive. Sad to say, many other magainzes in the field have gone under (e.g., *Magma, Mineralien Magazin, Gems & Mineral Realm,* and *Rockhound*), demonstrating how difficult it is to stay viable in mineralogy-related publishing.

In any case, if some of our readers still feel unable to cope with the price of a subscription, I have an offer to make. Simply send us your copy of volume 13, number 6 (the Gold Issue), in perfect mint condition, and we'll accept that in trade for a one-year subscription. A mint copy of volume 7, number 6 (Colorado-I) will buy you a three-year subscription. How many other magazines do you know of who give value like that? Try sending *National Geographic* or *Gourmet* or *Time* an old back issue in trade for a full year's subscription and see what they say! I'll accept up to 50 copies of the Gold Issue on this deal (more, if I hear from *other* readers willing to *pay* $27 for such returned copies . . . the current out-of-print price among dealers is closer to $50), and 50 copies of Colorado-I (currently worth $200). Frankly, I'll be surprised if more than five or ten people out of our 6,000 subscribers take me up on this. My point is simply that *Mineralogical Record* readers receive an almost unprecedented return on their subscription "investment." It is possible for a subscriber to sell off some back issues on the open market each year to finance his current subscription renewal, and go for who-knows-how-many years like this without ever having to put up "new" money!

Moving on to the question of quality in the magazine itself, the next three graphs show that aspects such as total pages published per year, number of color issues per year and number of color photos per year are *all up substantially*. In fact, this marks our first year wherein every issue has contained color photography . . . a milestone. It wasn't easy. We have benefited from no increase in circulation in the last few years, no increase in paid advertising and no increase in major donors. Although our annual auction does well, the take in constant-value dollars has fallen somewhat.

Readers who are wondering whether our continued survival is much of an accomplishment are referred to a recent interview* with Michael Hannan, publisher of over 30 magazine titles including special-interest journals. He states that publishers in general currently believe that "if you're producing and selling only 15,000 copies, you can't pay the costs of producing the magazine and getting it to press." Someone should tell him about the *Mineralogical Record,* hanging in there at only 7500–10,000 copies!

The improvements made in the *Mineralogical Record* have been possible only through (1) the continued support of our two major donors (Randolph Rothschild and our anonymous donor from Georgia), (2) meticulous financial management and careful shopping for the best price on services such as printing, mailing and color separations, and (3) refraining from hiring any additional editorial staff despite the increased work load.

I'm pleased to say that we *have* received a major donation (from an anonymous donor in New York) to help with part of the extra costs on the long-awaited *Silver Issue,* coming right up for January-

**Folio* magazine, August 1985, p. 148.

February. That issue will be a dandy . . . one more incentive not to let your subscription lapse just yet.

There is another reason why I wanted to describe some of these things in detail. And that is to point out that we do our very best to produce a magazine of lasting value, with the look and feel of prosperity; but we are still riding the fine line between red ink and black in the financial ledger. Just because we're looking pretty good these days, please don't assume that we no longer need your help. We do, very much. We need important (and even not-so-important) auction donations, and we really need one more donor for color work who is willing to provide $5,000 to $10,000 per year. I might also say that we appreciate our subscribers and advertisers simply sticking with us all these years . . . without that firm base we couldn't make it.

So there you are. Incidentally, we also have some exciting projects under way for the future and, although I've let the *Silver Issue* out of the bag, I'll maintain the suspense for the others this coming year. You'll just have to wait and see!

THE BRAZEAU REPORT

Edward Brazeau is the author of the *Standard Mineralogical Catalog* (now in its seventh edition), a comprehensive survey of market prices for mineral specimens. Every year or so he provides us with an overview to recent market trends as revealed by massive computer analysis of thousands of current prices. His report:

> Last year and the first half of this year have proven to be another good period for the mineral specimen market. Whereas most other collectibles were only beginning to recover from devaluations caused by the previous recession, mineral specimens continued the steady gains they enjoyed during those bad times. If you waited to purchase that special piece in the hope that it would come down in price you were most likely disappointed.
>
> The year 1984 saw overall increases in the prices of all categories of specimens, from reference-only quality to the very highest quality. Fortunately for buyers the torrid pace of price increases characterizing the previous years has largely subsided along with the inflation rate. But overall prices are still ahead of inflation, resulting in "real" appreciation.
>
> Highest quality specimens continued to lead the way for the mineral market. Price gains were generally the rule, with but a few exceptions. Those specimens which lost value typically did so only in response to more abundant supplies being found. As in the past, the future will probably see a significant increase in the price of extraordinary-quality specimens because demand almost always exceeds supply.
>
> The greatest change in recent performance involved the rare minerals. In the past, a new discovery of a rare species would typically emerge on the market at a relatively high price, followed in a while by a significant decrease and then a very gradual recovery. Lately, however, that decrease phase has been markedly less severe. Previous drops were probably the result of dealer "dumping" of unsold stocks after their hardcore clientele had been satisfied. Subsequently improved price stability may indicate that demand for rare species is increasing, or that dealers are buying and marketing their stock more judiciously.
>
> Average-quality specimens have also gained in value, in a few cases approaching the increases sustained by the higher value pieces. Average-quality specimens were very sluggish during the previous period and may now be experiencing a correction.
>
> Some upward movement was also noted in the low-quality specimens for the first time in several years. Lapidary materials, on the other hand, showed little or no gains and continued to languish.
>
> The strongest price increases occurred among the gemstone species, traditional favorites with intrinsic value transcending their specimen status. Big losers were few, generally only those decreasing significantly in rarity and those losing temporary fad value.
>
> And what about the future? We predict a continued appreciation in excess of the inflation rate, with the hottest market remaining the top-quality pieces. Downside risks still exist, but only in the case of prolific new discoveries affecting the rarity of previous finds. Double-digit appreciation, however, will probably not return unless the national economy goes on another inflation spree, or unless some new high-spending investors enter the market.
>
> E. Brazeau

As Louis Rukeyser always reminds his *Wall Street Week* viewers (probably for legal liability reasons), expressed predictions are not guaranteed.

MINERAL NEWS

Lanny Ream, well-known Northwestern author and collector, recently initiated a new monthly newsletter: *Mineral News.* The emphasis is largely on recent field discoveries of mineralogical interest, but such features as book reviews, symposium notices and advertisements are also included. The July 25 issue (vol. 1, no. 2) consists of four double-sided sheets computer-generated in 8½ x 11 format and stapled together at one corner. A subscription is $12 per year, from **MereSong Press, P.O. Box 1154, Coeur d'Alene, ID 83814.**

NEW YORK MINERALOGICAL CLUB

During the coming year the New York Mineralogical Club will be celebrating its 100th anniversary. The following notes on the history of the club were provided by Will Shulman.

The New York Mineralogical Club was formally organized on September 21, 1886, in the home of Professor Daniel S. Martin. The prime movers were George F. Kunz, B. B. Chamberlin and Professor Martin; they decided to hold monthly meetings at the home of a different member each month, with the host presiding, and so no president was named. Kunz (secretary), Chamberlin (treasurer), Professor Martin, Reverend J. Seldon Spencer and E. A. Hutchins comprised the executive committee; R. B. Whitfield and L. B. Gratacap were elected Club curators.

Few clubs today even have an elected curator, much less *two,* but the NYMC's excellent collection of minerals from the New York City area grew quickly to prominence. It was placed on exhibit in the Morgan Hall of the American Museum of Natural History. Fine specimens of xenotime, chrysoberyl, garnet, dumortierite, stilbite, beryl and tourmaline are highpoints of the collection (currently not on public display).

At the sixth meeting in March of 1887 the name *New York Mineralogical Club* was officially adopted, and a constitution and by-laws were approved shortly thereafter. In 1895 Kunz was elected the club's first president, a post he held for many years.

The club enjoyed many outstanding lectures throughout the years; among these was certainly the lecture given on October 28, 1886, by Augustus C. Hamlin of Mt. Mica, Maine, on the celebrated Mt. Mica tourmaline locality. He brought along a 27-cm gemmy green crystal for club members to admire, as well as an exhibit case filled with cut tourmalines.

From time to time the club has issued its own publications, perhaps the most famous of which is J. G. Manchester's book, *Minerals of New York City and its Environs* (1931). And a sizable number of club members (including those elected to honorary

The New York Mineralogical Club field trip to Penitentiary quarry, Snake Hill, New Jersey, on September 4, 1893 (photo courtesy of Carl and Shirley Krotki).

membership) have had new minerals named in their honor. Some of those new species were later discredited but the list (compiled by J. J. Peters) is nonetheless impressive for one club, and includes the following:

Clarence S. Bement (bementite)
Brian Mason (brianite, stenhuggarite)
M. Lazard Cahn (cahnite)
Frederick Canfield (canfieldite)
Marie Sklodowska Curie (sklodowskite)
Thomas Egleston (eglestonite)
George L. English (englishite)
Clifford Frondel (cliffordite, frondelite)
Victor Goldschmidt (goldschmidtite = sylvanite; goldschmidtine = stephanite)
William E. Hidden (hiddenite = green spodumene)
Albert F. Holden (holdenite)
W. W. Jefferis (jefferisite = vermiculite)
James F. Kemp (kempite)
Charles Locke Key (ludlockite, keyite)
George F. Kunz (kunzite = lavender spodumene)
Arthur Montgomery (montgomeryite)
Alfred J. Moses (mosesite)
William Niven (nivenite = uraninite)
Edwin Over (overite)
Charles Palache (charlesite, palacheite = botryogen?)
Louis Perloff (perloffite)
Joseph and Thomas Peters (petersite)
Frederick H. Pough (poughite)
Washington A. Roebling (roeblingite)
Austin F. Rogers (austinite)
Waldemar T. Schaller (schallerite)
Curt G. Segeler (segelerite)
John Sinkankas (sinkankasite)
Leonard J. Spencer (spencerite)
Hugo Strunz (strunzite)
Herbert P. Whitlock (whitlockite)
Neal Yedlin (nealite, yedlinite)

The New York Mineralogical Club is still an active, enthusiastic organization sponsoring prominent lecturers and adventurous and productive field trips. The membership roster maintains its traditional mixture of outstanding amateur and professional mineralogists.

GEMS & MINERALS ISSUES NEEDED

The Record Library's set of *Gems & Minerals* magazine is nearly complete. But we still need the following 12 issues: **1970** (August); **1971** (April, May); **1973** (December); **1975** (January, March, August); **1977** (January, March, July, October); and **1978** (November). Can someone help us out on these? We'll be happy to purchase them at any reasonable price.

W.E.W.

the mineralogy of Graves Mountain

Lincoln County, Georgia

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Graves Mountain, Georgia, is the world's premier location for large, multiply twinned rutile crystals. Active kyanite mining over the past several decades has resulted in a relatively large number of extremely fine specimens reaching the collector market. In addition to rutile, the mountain is well known for its abundant large lazulite crystals and stellate pyrophyllite.

INTRODUCTION

Graves Mountain is located in extreme western Lincoln County, Georgia, approximately 8 kilometers southwest of Lincolnton and 16 km east of Washington. It lies immediately south of U.S. Highway 378 and is shown on the *Aonia* 7.5-minute U.S.G.S. topographic quadrangle.

The mountain originally consisted of an approximately 2100-meter long, northeast-trending series of three hills connected by shallow saddles. These hills collectively form one of a group of generally similar monadnocks that occur to the northeast at irregular intervals at least to central North Carolina. The highest hill reached an elevation of 273 m but is now approximately 75 m lower as a result of mining. Maximum relief was approximately 100 m, the 550-foot topographic contour generally defining what was originally considered to be the base of the mountain. The summits of the two westernmost hills were unusually steep and craggy, and were once the object of many a horse and buggy picnic. Until December of 1984, the mountain was actively mined by the C-E Minerals Division of Combustion Engineering, Inc. It is currently operated by Pasco Mining Company and cannot be visited except with special permission.

HISTORY

Graves Mountain was first mentioned in the scientific literature by Professor C. U. Shepard (1859). Through a mutual friend, Shepard obtained from Dr. M. F. Stephenson unusual specimens of lazulite and pyrophyllite labeled simply "Lincoln County." For a while Shepard assumed these specimens were from the mineralogically better-known Lincoln County, North Carolina, locality. After what must have been considerable correspondence and at Shepard's insistence, Stephenson, with the help of two "miners," collected numerous lazulite, rutile and pyrophyllite specimens. Presumably, most of these specimens ended up in Shepard's possession and formed an important component of the various Shepard mineral collections, parts of which exist today more or less intact.

Apparently Graves Mountain was the site of only occasional collecting and leisure visits for several decades following Shepard's initial paper and distribution of Stephenson-collected material. Kunz (1892) formally recognized Professor Shepard's importance with respect to the worldwide distribution of Graves Mountain specimens and stated that "the rutile from this locality has realized at least $20,000 for cabinet specimens, and has supplied the collections of the world through the perseverance of Prof. Charles U.

Shepard." Testimony to Shepard's widespread mineralogical connections further lies in the number of European papers of the time dealing with Graves Mountain minerals. Chief among these are works by Haidinger (1860), Rose (1862), vom Rath (1891) and Mugge (1884, 1886 and 1887).

According to Zodac (1939), Kunz was so taken with Graves Mountain that he purchased the upper part of the mountain and allowed friends to work the area for specimens on a 50-50 basis. Pits on the northeast flank of the western summit and in the saddle between and west and central summits were the site of many later field trips.

The mountain gradually became the focus of serious geologic study around the beginning of the 20th century. Thomas L. Watson made a series of trips to the site between 1900 and 1911, publishing the results of this work in 1912. Concurrent with this effort, the Georgia Geological Survey directed Otto Veatch to undertake a reconnaissance investigation of the general region. More recent publications, among these the works of Hurst (1959), Espenshade and Potter (1960), and Hartley (1976), resulted from the economic evaluation and development of the kyanite-quartz rock making up the bulk of Graves Mountain.

By 1940 the potential value of what then seemed to be unlimited quantities of kyanite was recognized by a number of entrepreneurs, chief among them one Joel Watkins. Under Watkins' watchful eye a short adit was driven into the southeast face of the mountain in order to obtain a 4-ton bulk sample of the kyanite-quartz rock for flotation tests (Watkins, 1942). Although Watkins was successful in acquiring the mountain, the economics of kyanite mining in the early and mid-1940s precluded development of the proven resource.

A group of businessmen acquired the Watkins interest in the mountain in 1947 but likewise were unsuccessful in developing a market for the kyanite. In 1961 Dr. Paul Bennett acquired the deposit and placed it into production in 1963 as Aluminum Silicates, Inc. Combustion Engineering, Inc. bought the operation in 1965 and enlarged it to a point where it produced over half of the kyanite consumed annually in the United States (Hartley, 1976). Graves Mountain remains today a major source of kyanite for the production of mullite.

The specimen-producing history of the mountain is poorly documented for the years following the early days of the Shepard-Stephenson effort. Apparently, although lazulite and pyrophyllite were there for the taking, the easily collectible float rutile was quickly exhausted. Single specimens were no doubt available from the larger dealers as old collections were recycled or from small lots resulting from short excursions by local collectors. It appears that a major hiatus in serious Graves Mountain specimen collecting took place from the late nineteenth century until 1938 when Gilbert W. Withers was able to arrange with the owners to have the deposit professionally exploited for mineral specimens. The success of this venture is indicated by a full-page advertisement for Graves Mountain specimens taken out by Withers in the May, 1939, issue of *Rocks and Minerals*. The ad coincided nicely with an article by Zodac in the same issue on his collecting trip to the mountain.

Charles Upham Shepard (1804–1886)

George F. Kunz (1856–1932)

Little collecting activity occurred on the mountain for the next two decades with the exception of yearly outings by the Georgia Mineral Society. Small lots of exceptional rutile were occasionally recovered by very ardent digging in the area of the old rutile pits in the saddle between the two westerly summits.

All previous finds were eclipsed by specimens recovered by miners once active exploitation of the kyanite orebody began. Fortunately for the mineralogical community, a few tenaciously patient collectors were peripherally connected with the mining operation and its many supporting activities. Through the efforts of these few persons, many of what must be the finest rutile specimens in existence have been saved from the crusher.

GEOLOGY

In simplest terms, Graves Mountain consists of a steeply dipping, elongate lens of relatively resistant, somewhat variable metasedimentary and metavolcanic rock dominated by locally kyanitic quartz-sericite schist and relatively massive sericite-kyanite-quartz rock. Despite this seemingly straightforward situation and the loca-

tion's historical popularity among persons of geologic bent, it remained until the comprehensive study of Hurst (1959) for the details of the mountain's geology to begin to be unraveled. A great deal of subsequent study has gone into the geology of the immediate Graves Mountain area due to its economic importance with respect to kyanite and the recognition of its base and precious metals potential. The origin and geologic history of Graves Mountain are understood with a fair degree of confidence today because of this work.

Graves Mountain lies within a thick sequence of metamorphosed volcanic and sedimentary rock known as the Little River Series. These units have been correlated by essentially all modern workers with the better-known Carolina Slate Belt. Both sequences have been dated as Lower Paleozoic.

Figure 1. **Location and topography; *Anonia* 7.5-minute quadrangle (1972). Today the mine area is considerably more extensive than shown.**

The dominant rock unit on the mountain is pyritic sericite-kyanite-quartz rock, a kyanite-quartz granofels commonly referred to simply as kyanite quartzite. Individual quartzite units range up to approximately 15 m thick; the more massive zones formed the resistant crags which characterized the area prior to mining. Locally, the unit is conglomeratic. Hurst (1959) divided the unit into two facies based on grain size, and treated the conglomeratic zones separately. The distinction of three varieties of kyanite quartzite based on degree of weathering and weathering profile was made by Hartley (1976). Point count analyses of the unit by Hurst (1959) show quartz ranging between 33.9% and 72.8% and kyanite between 2.1% and 59.5%. Rutile was a consistent accessory constituting up to 1.4% of his samples.

The other major rock unit, quartz-sericite schist, occurs locally interbedded with the dominant kyanite quartzite. The rock contains ubiquitous pyrite in amounts ranging up to 5%. Foliation in the unit is typically parallel with bedding in adjacent kyanite quartzite. The quartz-sericite schist, like the kyanite quartzite, exists in several varieties distinguished by pyrite content and degree of weathering.

The sequence of interbedded kyanite quartzite and quartz-sericite schist is complicated by an intersecting network of relatively late, massive white quartz veins. These veins are characterized locally by the development of coarse-grained stellate pyrophyllite and relatively coarse kyanite grain size in adjacent quartzite. The museum-quality rutile for which the mountain is famous appears to be genetically related to the formation of these veins.

Graves Mountain is elongate along a general N 70° E direction

Figure 2. **Craggy quartzite outcrop near the western summit of Graves Mountain. Photo by W. S. Yeats ca. 1900.**

Figure 3. **Kyanite quartzite boulders showing preferential weathering of granular quartz; kyanite aggregates stand out in bold relief from the pitted, cavernous surface. Western summit of Graves Mountain; photo by W. S. Yeats ca. 1900.**

generally parallel with the regional trend of the host Little River Series. However, individual structural attitudes vary greatly on the mountain and can be interpreted in a number of ways (Radcliffe, 1978). Outcrop patterns mapped by both Hurst (1959) and Espenshade and Potter (1960) suggest the presence of rather tight, northeast-trending folds. A system of "shear fractures or fracture cleavages" was identified by Hurst (1959).

The origin of Graves Mountain and similar kyanite "quartzites" has been the topic of intermittently hot debate for a number of years. One of the earliest and most interesting ideas was proposed by F. A. Genth (1873) who thought that all of the minerals except quartz and rutile were produced by the alteration of corundum. Watson and Watson (1912) were undecided except that regional metamorphism was invoked as an important factor. Most modern workers impose various stages of alteration and metamorphism of volcanic rocks, in part vitric tuffs. Hurst (1959) was able to discern five developmental stages, all related to metamorphism and alteration of original tuffaceous sediments and intercalated gravels. A somewhat more general origin for the Graves Mountain-type kyanite "quartzite" involving the local replacement of an igneous protolith by alumina and silica was described by Espenshade and Potter (1960). A rather logical series of six fundamental steps beginning with island arc volcanism, progressing through very local intense leaching of a resultant tuff bed by ascending fluids and subsequent greenschist-facies regional metamorphism, to weathering and erosion has been proposed by Hartley (1976). Variations on this theme have been suggested by others including Reusing (1979) and Carpenter (1982). A divergent hypothesis has been proposed by Radcliffe (1978) whereby the Graves Mountain-type deposits are the result of regional metamorphism of local sandy kaolin deposits that mark the position of a paleo-shoreline.

MINERALOGY

Various aspects of the mineralogy of Graves Mountain have been presented since Shepard's original work in 1859. However, only those presenting specific data on rutile or lazulite written during the latter half of the nineteenth century, and the more comprehensive works of Watson and Watson (1912) and Hurst (1959) treat its mineralogy as more than a relatively minor topic related to economic geology or geologic origin. Almost no detailed mineralogical studies have been published since mining began. Much of the following material is synthesized from a wide variety of data gathered from a large number of publications and reports, discussions with former geologists of C-E Minerals, and personal observations made between 1958 and 1972.

Alunite $KAl_3(SO_4)(OH)_6$

Pale yellow masses of alunite filling small cavities in weathered kyanite quartzite are reported by Hurst (1959). Tiny quartz crystals and porous masses of gray barite are typically admixed with alunite. The alunite-filled cavities have the shape of tabular barite crystals and presumably resulted from a series of chemical weathering reactions involving pyrite, barite, kyanite and possibly lazulite.

Andalusite Al_2SiO_5

Hurst (1959) recognized andalusite at two places on the mountain, both now within the mined-out area. One occurrence was in small white-to-gray inclusions in lazulite crystals. The second occurrence was as a minor constituent of thin flesh-colored veinlets

Figure 4. **Current open-pit mining on the western summit of Graves Mountain. Photo by David Baskin.**

that transected kyanite quartzite. Associated minerals were alunite, gibbsite and pyrophyllite. Andalusite is the dominant aluminosilicate mineral in several economically important southeastern deposits of the general Graves Mountain type (Espenshade and Potter, 1960).

Barite $BaSO_4$

Quartzite containing small drusy cavities filled primarily with barite was described by Shepard (1859). The barite was both massive and crystalline, and occurred with minute transparent quartz crystals and microscopic crystals of sulfur. Stubby euhedral barite crystals up to 1.3 cm long occur in the more siliceous parts of the coarse kyanite zone about 50 m south of the saddle (Hurst, 1959). In unweathered rock the crystals are colorless and easily overlooked. The crystals are scattered and without apparent orientation. During the course of mining, small lenticular cavities lined with 1–2 cm long tabular gray barite crystals were encountered. Modest specimens of this type of material occasionally have been available.

Gibbsite $Al(OH)_3$

Hurst (1959) reports that gibbsite occurs on Graves Mountain in minor amounts in the late veinlets containing andalusite and in weathered lazulite crystals.

Goethite-Hematite $FeO(OH)$–Fe_2O_3

Within the zone of weathering, iron oxides are everywhere present and are locally very abundant. Yellow-brown stain on virtually all weathered rock surfaces is this material, as is the red-brown

Figure 5. **Ed Hamlin (now deceased), one of the most avid of Graves Mountain collectors, holding two fine rutile specimens. Photo by Esther Dunn.**

coatings on the interior of cubic cavities left after the chemical weathering of pyrite. Prior to mining, large (up to 1 m in diameter) masses of botryoidal, cavernous iron oxides occurred as locally abundant float in and around the old rutile prospects. Such masses occasionally hosted small to very large rutile crystals and, while superficially appearing to be relatively pure iron oxide, were actually iron oxide-coated and impregnated kyanite. Microscopic examination of iron oxide-rich material from the old rutile prospects by Watson and Watson (1912) indicated that hematite as massive granular aggregates of steel gray to red color filled spaces between

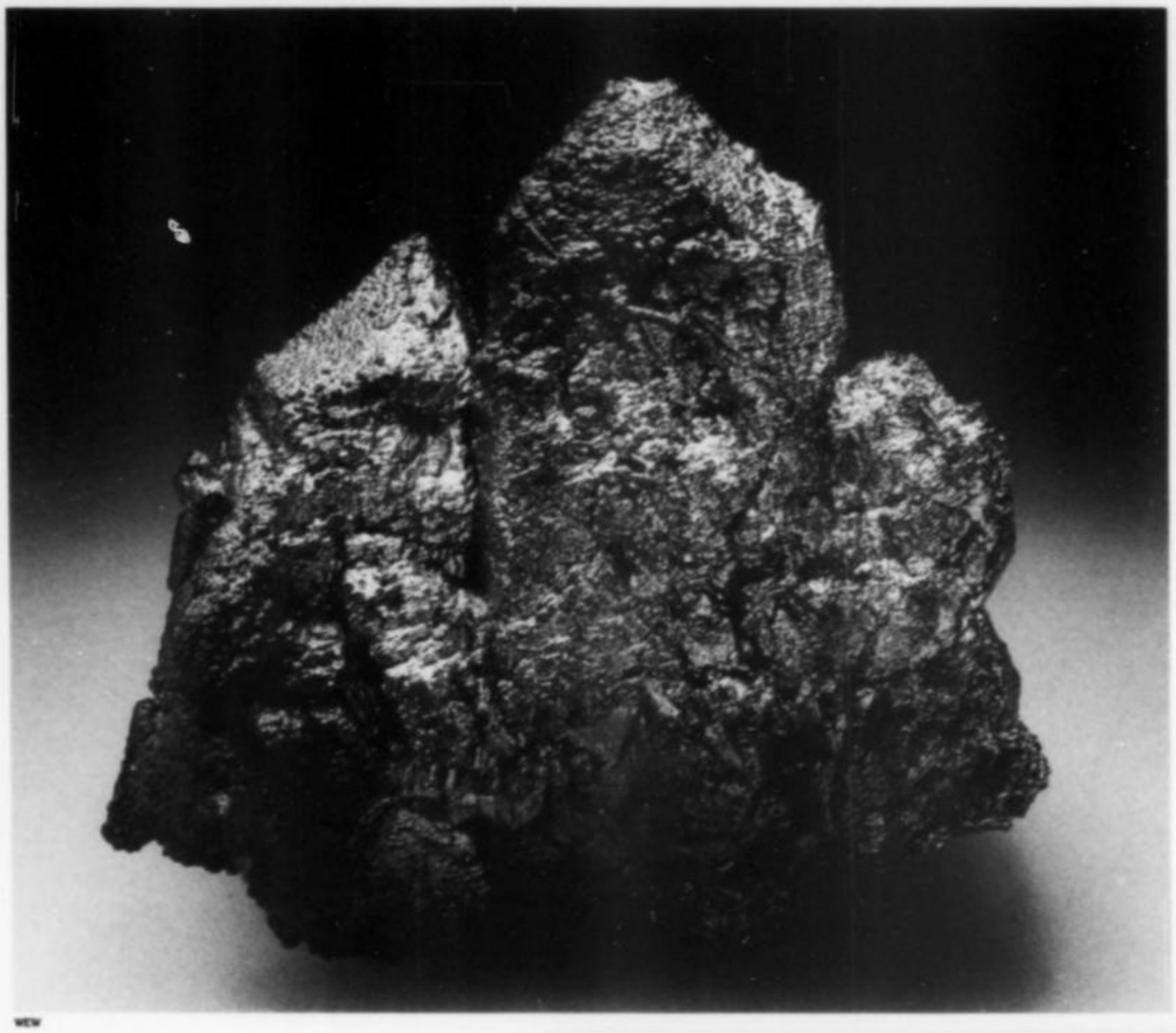
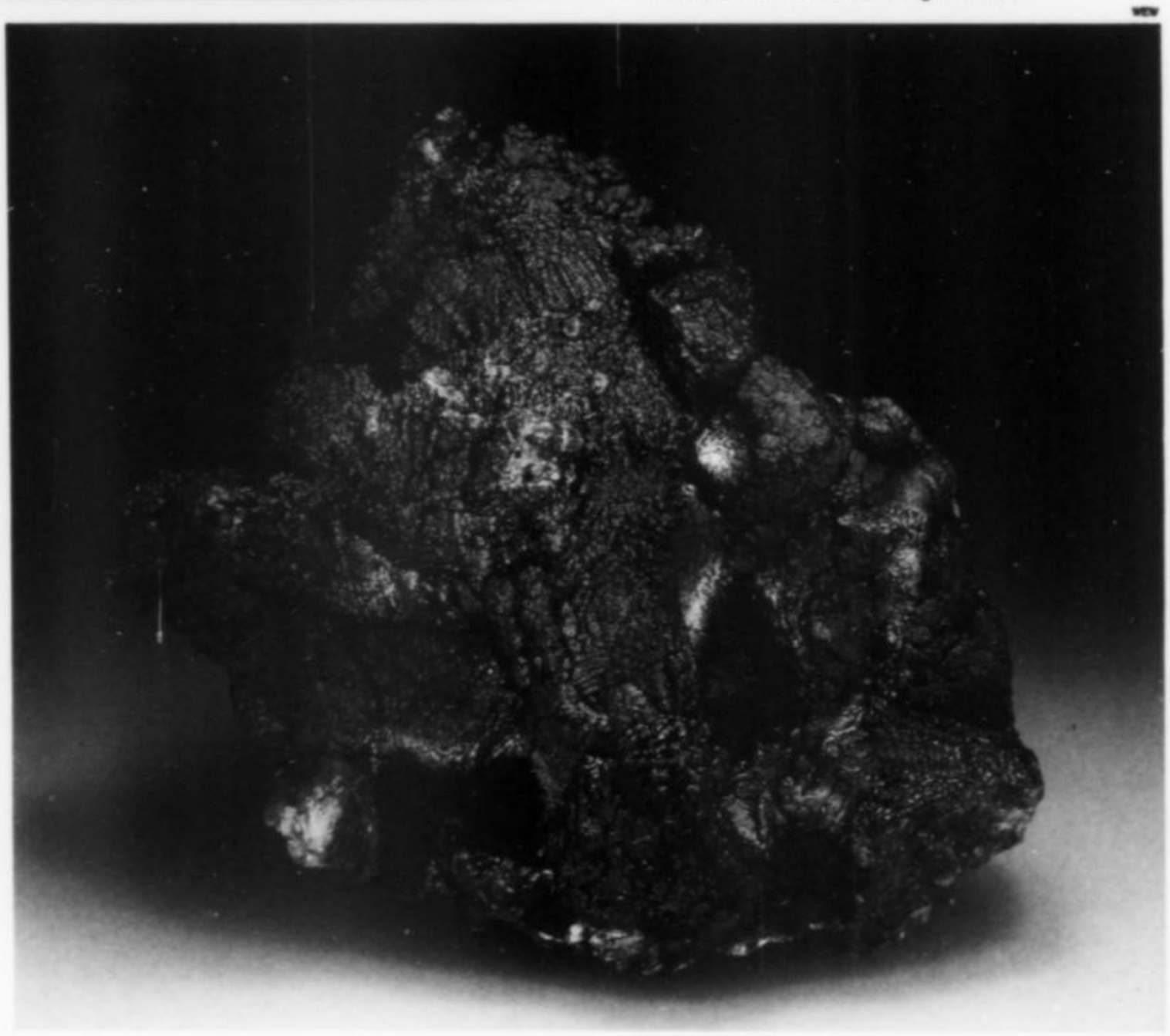


Figure 6. **Iridescent coating of iron oxides on large quartz crystals; 11 cm across. David M. Crawford specimen.**

Figure 7. **Iridescent coating of iron oxides on large quartz crystals; 10 cm across. David M. Crawford specimen.**



kyanite crystals and locally penetrated individual kyanite grains along cleavage and fracture planes. Specimens with brilliantly iridescent surfaces were relatively common and, more recently, have been recovered as very colorful material from within the active mine.

Much of the more massive iron oxide is found in near proximity to quartz veins and lenses, is preferentially associated with a general coarsening of grain size in kyanite quartzite, and may be at least partially attributable to late hydrothermal processes rather than simply to weathering. Supporting this conclusion is the fact that material preliminarily identified as low-temperature goethite has been shown to be aluminum-substituted hematite (Radcliffe, 1978).

Gold Au

Graves Mountain was one of the early sites of gold prospecting in Georgia. Shepard (1859) reported that gold had been found in the

Figure 8. **Iridescent coating of iron oxides on kyanite crystals, 8.5 cm across. David M. Crawford specimen.**

quartz-kyanite rock near the "southern exremity of the formation, where it becomes more schistose and embraces minute crystals of pyrites." Prior to the development of the kyanite mine several shallow shafts and trenches traditionally thought to be the site of former gold prospecting could be seen near the southwest base of the mountain and near the northeast summit. Although gold has not been formally reported from the mountain in modern times, byproduct pyrite from the kyanite operation is reported to contain low though significant amounts of gold. Gold can be panned from many nearby streams and the general sequence of volcanic units that hosts Graves Mountain has been the focus of recent gold exploration by major mining companies.

Ilmenite $FeTiO_3$

Although not common in megascopically identifiable grains, ilmenite has been determined to account for approximately 50% of the titanium in the kyanite quartzite (Robert H. Carpenter, personal communication). Johnston (1935) mentions that specimens of

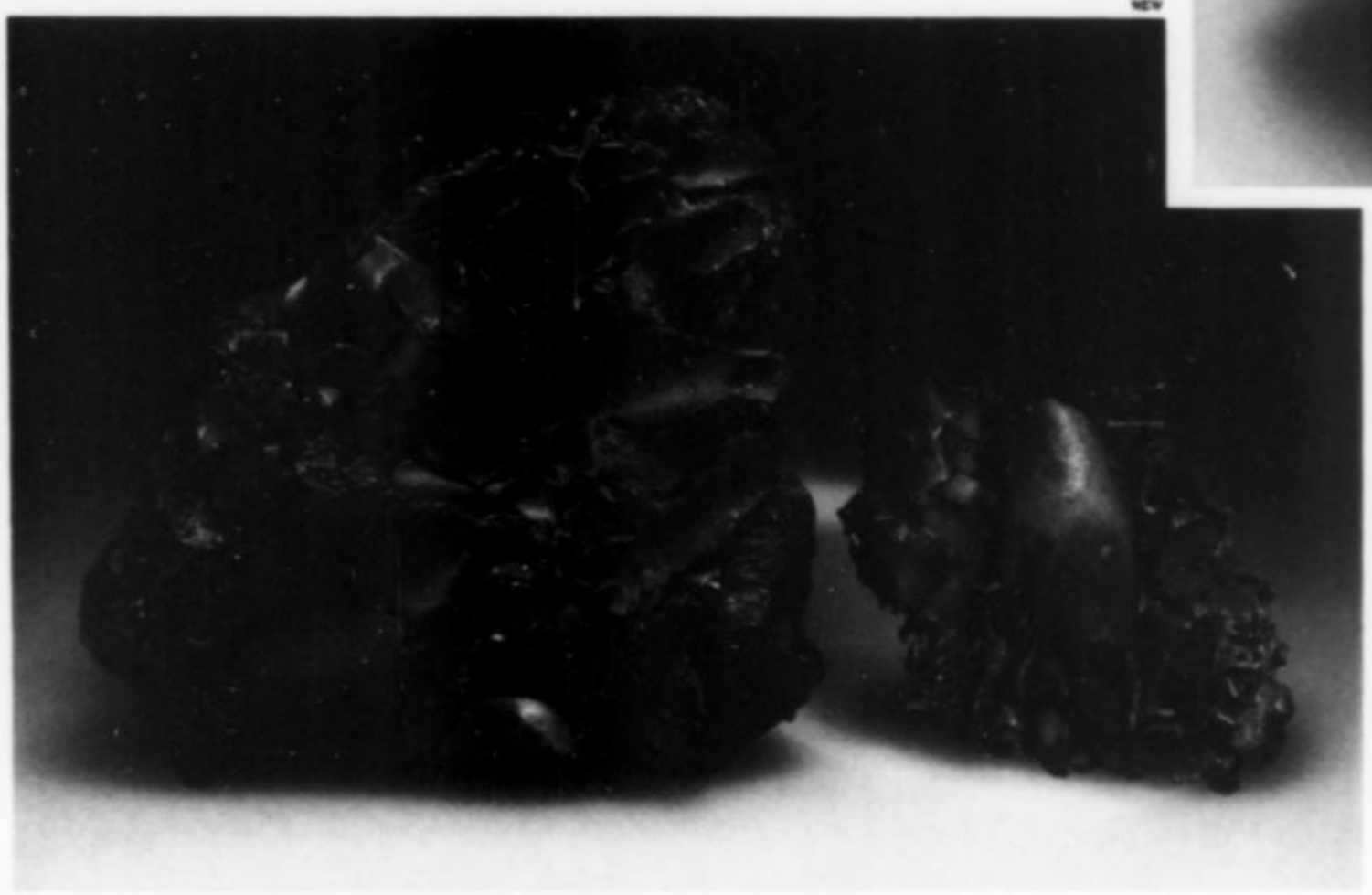


Figure 9. **Thin iridescent coating of iron oxides on kyanite crystals, 6.5 cm tall. James Fowler collection.**

Figure 10. **Peculiar curled flakes of kyanite coated by iridescent iron oxides; 5.5 and 9.3 cm. James Fowler collection.**

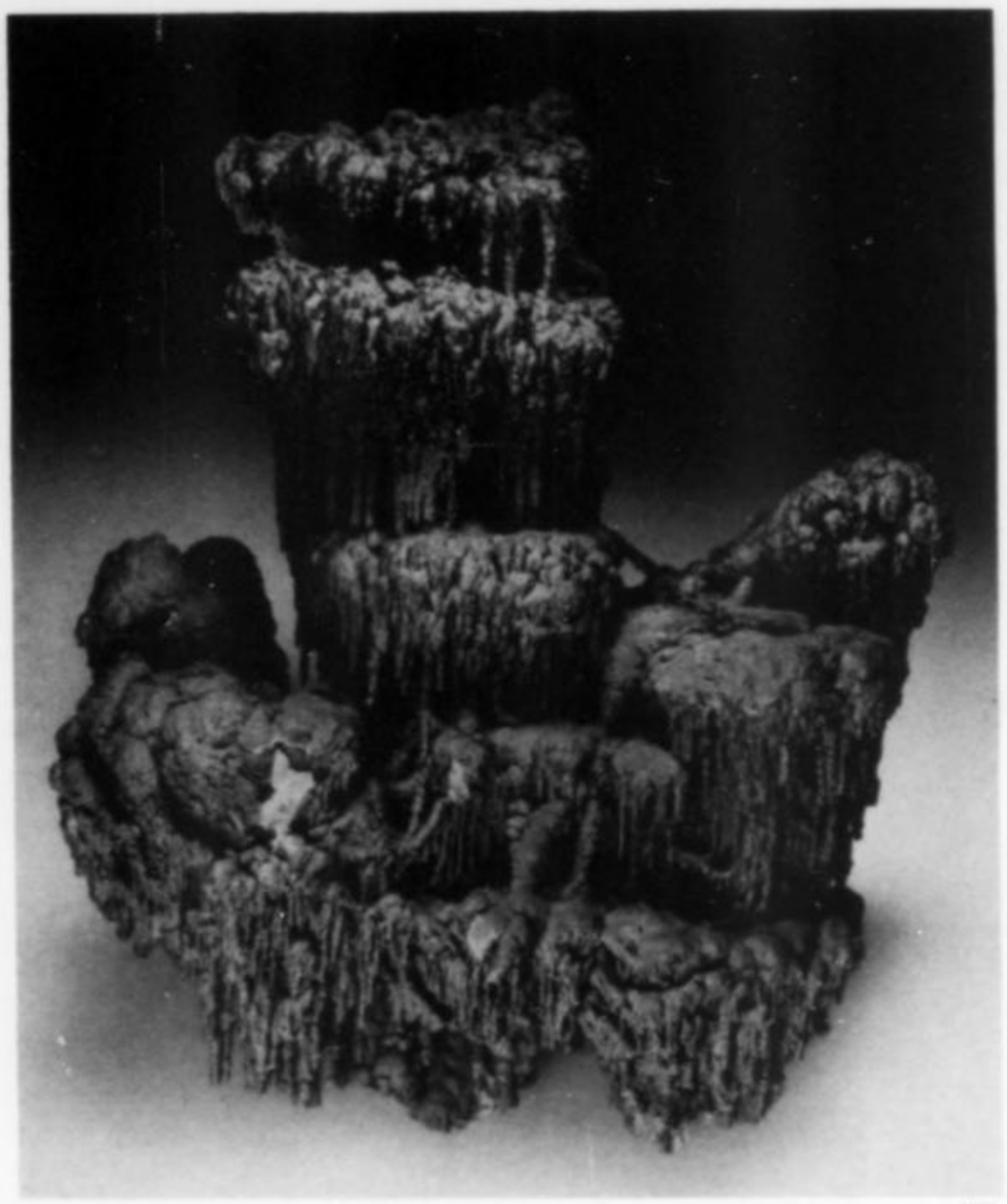


Figure 11. **Stalactitic goethite, 11 cm tall. James Fowler collection.**

vein quartz containing large tabular ilmenite crystals were once found on the north slope of the mountain as float. Platy ilmenite crystals typically less than 1 cm across were once relatively abundant in rainwashed ditches on the northwest side of the saddle between the two main summits (Hartley, 1976). A number of relatively fine ilmenite specimens consisting of euhedral plates up to 8 cm across in massive white quartz were recovered from fields at the north base of the mountain during the 1950s. The ilmenite crystals exhibited complex forms, a metallic luster, and triangular growth features on {0001}.

Jarosite $KFe_3(SO_4)_2(OH)_6$

Brilliant yellow jarosite occurs with phosphosiderite in altered lazulite crystals near the bottom of the zone of weathering where exposed in the active mine (Henry Barwood, personal communication). The jarosite occurs as minute complex crystals and as yellow powder. Superficially similar alunite, jarosite and sulfur at Graves Mountain are easily confused in the field.

Kaolinite $Al_2Si_2O_5(OH)_4$

Minor kaolinite, at least some of which is considered to be of late hydrothermal origin (Hurst, 1959), is widespread. It is most notable as white coronas surrounding porphyroblastic kyanite. The kaolinite is either intimately mixed with pyrophyllite or surrounds pyrophyllite which in turn encloses kyanite.

Kyanite Al_2SiO_5

With the exception of quartz, kyanite is the most abundant mineral at Graves Mountain and is the object of current economic exploitation. Approximately 10% of the "kyanite quartzite" is kyanite, with wide zones containing up to 40%. The original bold craggy outcrops were the weathered remnants of coarse-grained kyanite quartzite characterized by thin stringers and scattered porphyroblasts of small white to light-gray or green kyanite crystals. Such kyanite stringers are usually less than 1 cm thick and are closely spaced and parallel in places, but also form networks of randomly oriented veinlets. Clots and veinlets of kyanite once stood out as rough projections and ribs on the weathered outcrops, the fine-grained interstitial quartz matrix having been physically weathered away.

The detailed work of Hurst (1959) indicates that kyanite occurs in three distinct modes at Graves Mountain. The most obvious is in aggregates along foliation and fracture planes criss-crossing the rock as described above. Kyanite is also shown to occur in clots of increased grain size adjacent to and within late quartz veins, and simply as porphyroblastic crystals and groups of crystals disseminated without apparent systematic arrangement. Most Graves Mountain kyanite occurs in the third mode as pale green, subhedral to euhedral grains less than 2 cm in length.

Lazulite $MgAl_2(PO_4)_2(OH)_2$

The first Graves Mountain mineral species to be described in detail was lazulite. Shepard (1859) described the most common crystal forms and twin habit, illustrating his work with crystal drawings provided by E. S. Dana. In 1883 Lasaulx presented in detail the optical properties of lazulite using a Graves Mountain sample. The occurrence of the mineral has been further described in varying detail by Watson and Watson (1912), Watson (1921) and Hurst (1959). Pecora and Fahey (1950) briefly discussed the morphology of Graves Mountain lazulite, illustrated several crystals, provided chemical analyses for major and trace elements, listed X-ray data and compared other occurrences.

Most lazulite occurs in azure-blue or ultramarine-blue euhedral crystals that generally are less than 1 cm in length but which are known up to 8 cm in greatest dimension. Only occasionally are anhedral masses noted. Typically, euhedral lazulite occurs disseminated throughout irregular zones in the kyanite quartzite. When present, lazulite makes up from 1 to 5% of the rock with zones less than 1 m thick containing as much as 15% (Hurst, 1959). Prior to mining it was shown by Hurst (1959) that lazulite occurred over a wide zone that trended northeast-southwest across the mountain and seemed to be most abundant not in specific "quartzite" beds, but in silica-rich bands. After significant mining had taken place, Radcliffe (1978) felt that a distinct lazulite-bearing kyanite-pyrite-rutile quartzite bounded the kyanite orebody on the southeast. Lazulite has not been found as a mineral specifically associated with late quartz veins at this location.

Graves Mountain lazulite crystals vary from acute pyramids with dominant {111} and {$\bar{1}$11} faces, to tabular habits having distorted development of {111} or {$\bar{1}$11}. Complex modifications of this simple habit include development of {100}, {010}, {011}, {110}, {101}, {112} and several higher ordered pyramids (Goldschmidt, 1918). Twinning on (100) is very common and crystals twinned by this habit were considered by Shepard (1859) to be the most abundant form of lazulite found on the mountain. Many of the largest crystals found there exhibit this type of twin.

Most pre-mining Graves Mountain lazulite crystals are light blue, grayish blue or mottled blue and white. These crystals all originated from the southeast side's craggy quartzite outcrops and are more or less weathered. Larger crystals recovered from beneath the zone of weathering in the active mine are occasionally so dark blue as to appear almost black. When broken, these crystals are glassy and exhibit a conchoidal fracture. Large undamaged crystals are very scarce since virtually all are essentially frozen in very tough kyanite quartzite matrix. However, occasionally zones are found in which lazulite with crystal faces coated with muscovite or pyrophyllite occur. Careful scraping and cleaning of these crystals can yield exceptional specimens. From time to time large blocks of gray, pyrite-rich, fine-grained equigranular quartzite are recovered that contain randomly distributed lazulite crystals up to 3 cm in cross sectional

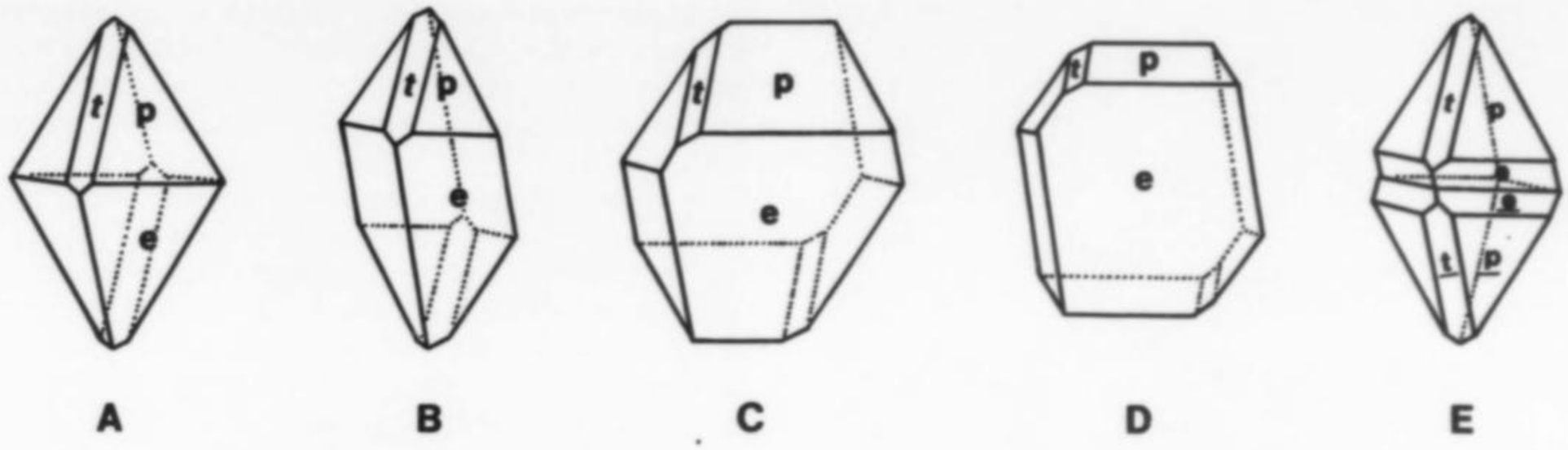


Figure 12. **Graves Mountain lazulite crystals showing the transition from normal, equant development of the acute dipyramid (A) to the distorted tabular habit having the same forms (D). The (100) twin is also shown (E). Redrawn from Shepard (1859).**

dimension. When slabbed and polished, unusually attractive specimens result.

Most lazulite crystals contain visible inclusions of colorless quartz grains or red-brown rutile. Less common inclusions are andalusite, sericite and pyrophyllite (Hurst, 1959). Weathered lazulite may locally contain cavities partially filled with a number of late minerals including gibbsite and phosphosiderite.

Magnetite Fe_3O_4

Magnetite occurs as a relatively uncommon accessory mineral of the kyanite quartzite (Reusing, 1979). It is almost always fine-grained and typically not recognized except during the petrographic examination of polished thin-sections.

Muscovite $KAl_2Si_3O_{10}(OH)_2$

Fine to medium-grained white mica is very widely distributed as a major constituent of the two main rock types. It occurs in amounts up to 74.6% in quartz-sericite schist collected from the south side of the mountain (Hurst, 1959). Work by Hurst (1959) indicated that much of the "sericite" so locally abundant on Graves Mountain is at least in part the sodium analog of muscovite, paragonite. Brilliant green mica that occurs locally within the active mine is typically referred to as fuschite. This mica has been shown to contain less than 0.1% chromium and is most likely a barium-rich variety instead (Robert H. Carpenter, personal communication). The formation of late veinlets of white mica has been identified as the final alteration stage at Graves Mountain by Carpenter (1982).

Paragonite $NaAl_2(Si_3Al)O_{10}(OH)$

A relatively important percentage of the common white micas on Graves Mountain is thought to be paragonite (Hurst, 1959). Paragonite and muscovite cannot be distinguished from each other visually and care must be taken in ascribing white micas to a particular species. Preliminary work by Hurst (1959) on white micas from nearby country rock schists indicated that paragonite was of rare occurrence except as a mineral directly related to the Graves Mountain alteration assemblage.

Phosphosiderite $FePO_4 \cdot 2H_2O$

Phosphosiderite has been identified by Henry Barwood (personal communication) as occurring with jarosite as an alteration product of lazulite. The mineral occurs as light pink to rose-red aggregates of microscopic crystals in cavities in lazulite.

Pyrite FeS_2

Pyrite is ubiquitous in the fresh bluish gray kyanite quartzite exposed below the zone of weathering in the active pit. The pyrite occurs as small cubes and aggregates, usually less than 3 mm in diameter. Pyrite content is variable, ranging typically between 0.5% and 4.9%, but locally can constitute as much as 10% of the kyanite-rich rock. Pyrite is separated in a flotation plant and sold as high purity "glass maker's grade" for use as a coloring agent in such products as brown beer bottles.

Pyrophyllite $Al_2Si_4O_{10}(OH)_2$

Unusual pyrophyllite specimens have been known from Graves Mountain since the original work of Shepard (1859). Most pyrophyllite occurs as intergrown stellate aggregates of brown, tan or white prismatic crystals. Individual aggregates vary from 5 mm to 3 cm in diameter. Within the active mine attractive white pyrophyllite aggregates have been found in dark brown to black iron oxide matrix.

Pyrophyllite occurs in at least three modes, each suggesting a relatively late position in the paragenetic sequence. It occurs throughout a large area underlain by kyanite quartzite as a fine-grained alteration product around the margin of kyanite grains,

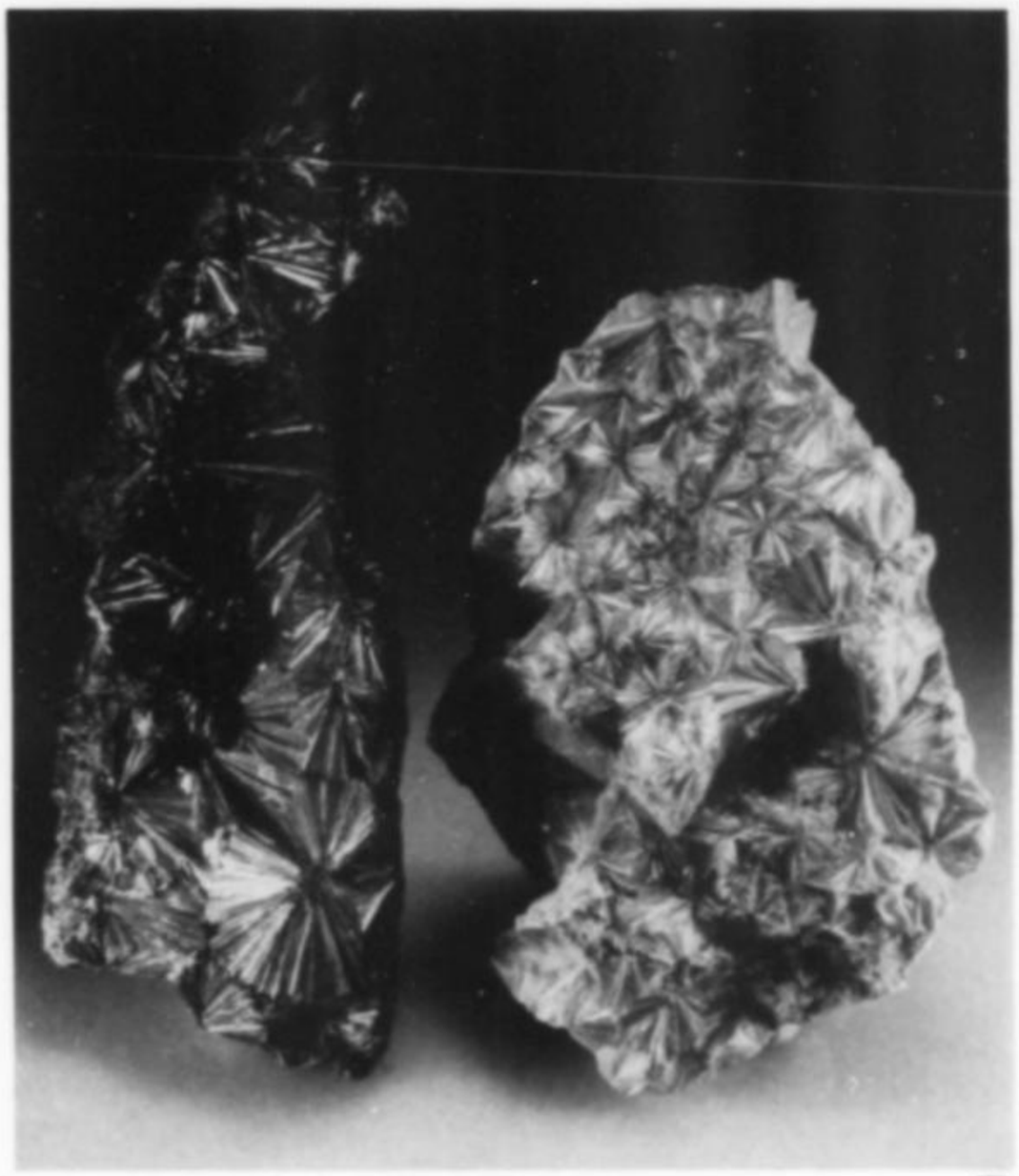


Figure 13. **Typical Graves Mountain pyrophyllite specimens, pale yellow to iron-red in color; the largest is 14 cm. James Fowler collection.**

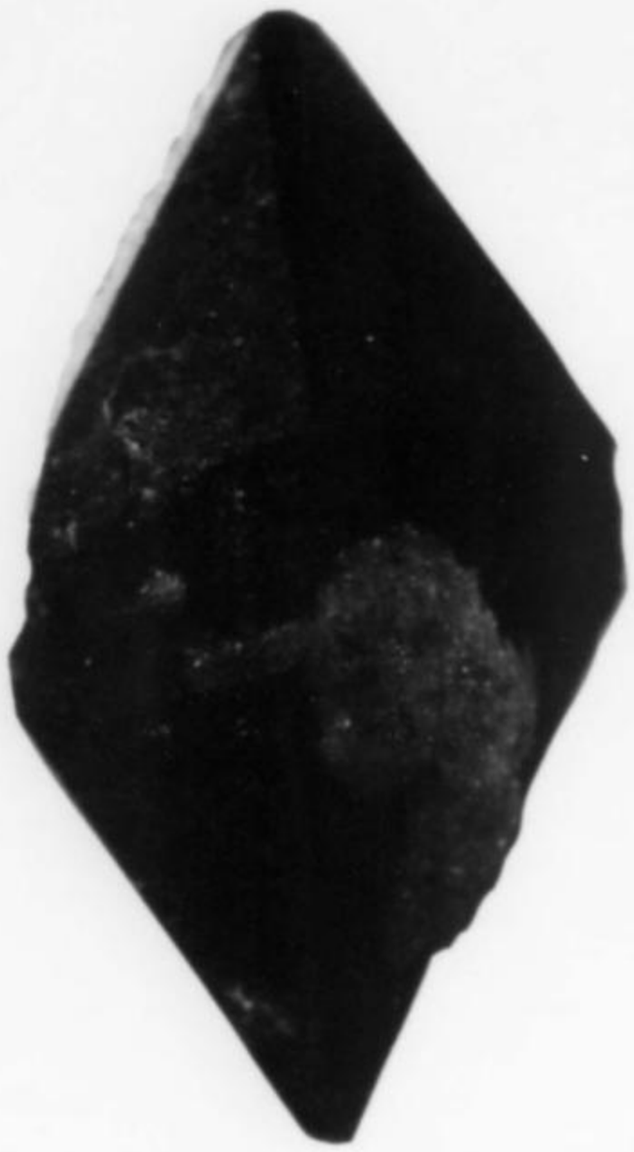


Figure 14. **Doubly terminated lazulite crystal showing contact twinning on (100); 2.3 cm. William Warren collection; photo by John Muntyan.**

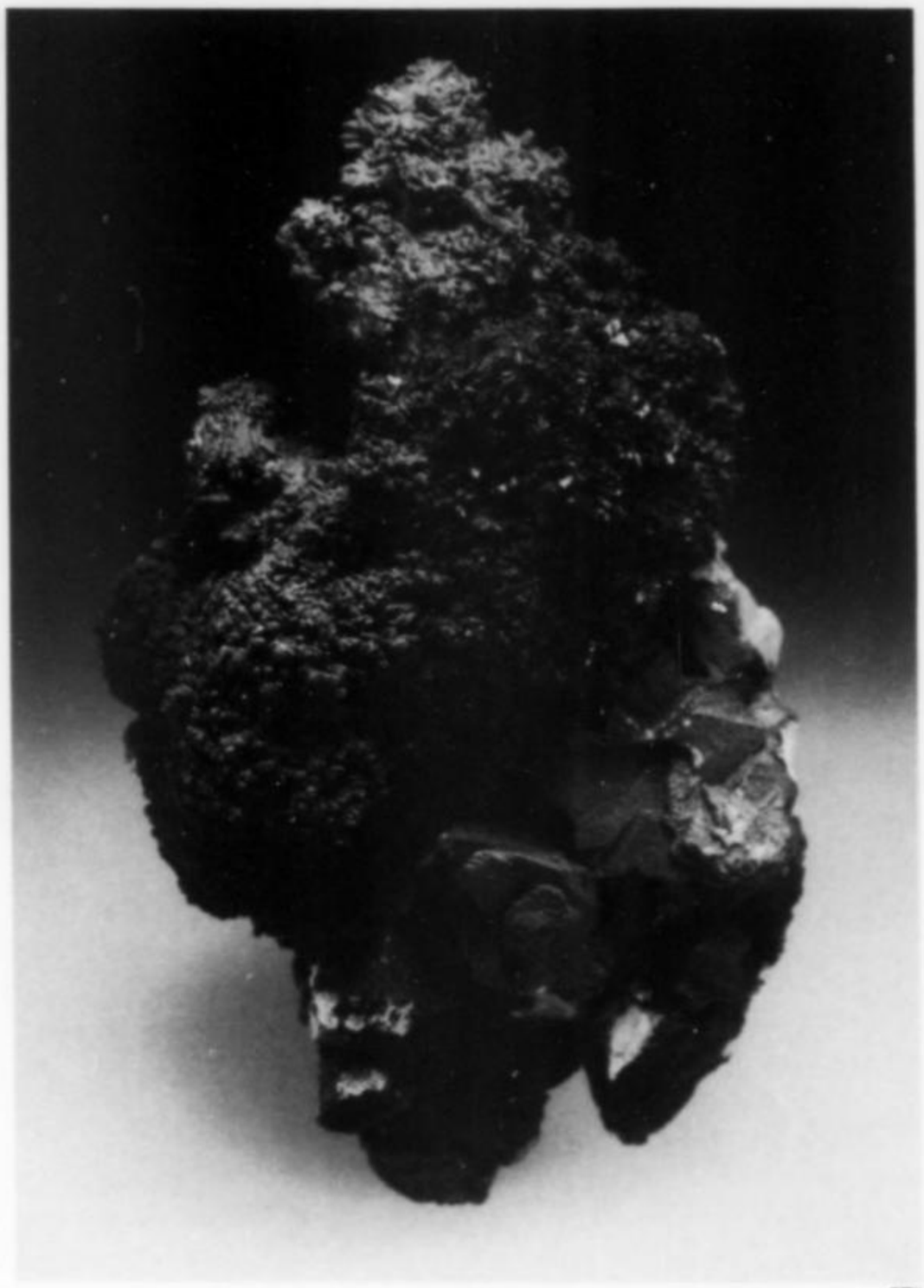


Figure 15. **Iridescent iron oxide coating on rare, free-growing, terminated pyrophyllite crystals and quartz; 7.3 cm tall. James Fowler collection.**

and as irregular masses up to 25 cm in greatest dimension in the kyanite-rich rock. Hurst (1959) noted the occurrence of narrow pyrophyllite veins that formed sets cutting the kyanite quartzite in a N 60–70° W direction. Coarse-grained aggregates of pyrophyllite crystals also commonly occur along the margins of quartz veins where it forms the matrix for typically small though lustrous rutile crystals. Occasionally quartz veins are brecciated with individual quartz fragments frozen in a cement of stellate pyrophyllite.

Quartz SiO_2

The most widespread and abundant mineral at Graves Mountain is quartz. It is a primary constituent of each of the major rock units, typically comprising more than 70% of the kyanite quartzite (Hurst, 1959). In this unit it typically forms the fine-grained saccharoidal matrix for coarser-grained kyanite. Locally, quartz veins and lenses up to 1 m thick are relatively abundant. The quartz is white, translucent and may contain coarse stellate pyrophyllite, rutile crystals or euhedral transparent kyanite. Coarsening of grain size in host units immediately adjacent to quartz veins is common. Occasionally quartz veins containing lens-like open cavities are encountered in kyanite quartzite. These cavities commonly contain somewhat crude, iron oxide-coated quartz crystals up to 5 cm in diameter and 10 cm long. Rarely, large euhedral rutile crystals occur intergrown with these quartz crystals. In almost every instance good specimens can only be generated by mechanically removing the very tenacious iron oxide coatings.

Rutile TiO_2

Rutile is the mineral for which Graves Mountain is best known. Specimens of Graves Mountain rutile grace virtually all of the world's major museum collections and have no close rivals in terms of crystal perfection, luster and size. All of the early rutile specimens were recovered from float and colluvium on the slopes of the mountain and within the saddle separating the westernmost summits. Shepard (1859) described "gigantic" rutile crystals weighing upwards of 0.5 kg (1 pound) and "possessed of much regularity of crystalline form." Crystals weighing up to 5.5 kg (12 pounds) are mentioned by Stephenson (1878). Watson and Watson (1912) report rutile crystals up to 12.5 cm (5 inches) and mention a personal communication from Kunz stating that fine single crystals weighing up to 1.8 kg had been found.

Since the advent of kyanite mining, an inestimable quantity of rutile specimens has been recovered from Graves Mountain, typically through the efforts of miners and diligent collectors. Crystals up to an impressive 25 cm in length and a weight of 8 kg have been found, as have many matrix specimens in qualities unmatched by the early float material.

The best Graves Mountain rutile is lustrous black with mirror-like faces that typically exhibit brilliant orange-red internal reflections. So taken with the beauty and perfection of these crystals was Shepard (1859) that he commented that "they are all more remarkable for their symmetry and polish, than any I have seen. Some are fully equal in luster to the brilliant crystals of cassiterite from Cornwall or Bohemia." The crystals exhibiting the most brilliant luster and perfection are typically found in more or less massive, iron-stained kyanite aggregates or in quartz crystal-lined pockets in white quartz veins.

Graves Mountain rutile is morphologically complex. A selection of crystal drawings that illustrate the most common variations in crystallographic habit and twinning is shown here. Graves Mountain rutile typically forms either simple twins on (101) or cyclic twins with (101) as the twin plan. Matters are commonly complicated by unequal form development. Eightlings are common, as

Figure 16. **Superb 2.8-cm pseudo-octahedral crystal of rutile with iron oxide coated kyanite. James Fowler collection.**

Figure 17. **Large rutile crystals on 11-cm matrix. The crystals are completely covered by a layer of iron oxide which must be carefully flaked off. Nearly all fine rutile crystals known from Graves Mountain were originally found coated. James Fowler collection.**

are sixlings. Both eightlings and sixlings typically exhibit eight or six-sided re-entrant cavities at the apex of the twins. Small crystals of this type (2 cm or less) are often perfectly developed. Fourlings and trillings are less common. It is almost impossible to find a Graves Mountain rutile that does not exhibit at least simple (101) contact twinning. The rare untwinned crystal usually is composed of the tetragonal prisms {100} and {110}, terminated by {101} and {111} dipyramids. Crystals with highly developed striations parallel to edges are locally common, particularly those found in close association with pyrophyllite veins.

The cause of the crystallographic complexity of Graves Mountain rutile is unknown. However, work by Marsh and Sheridan

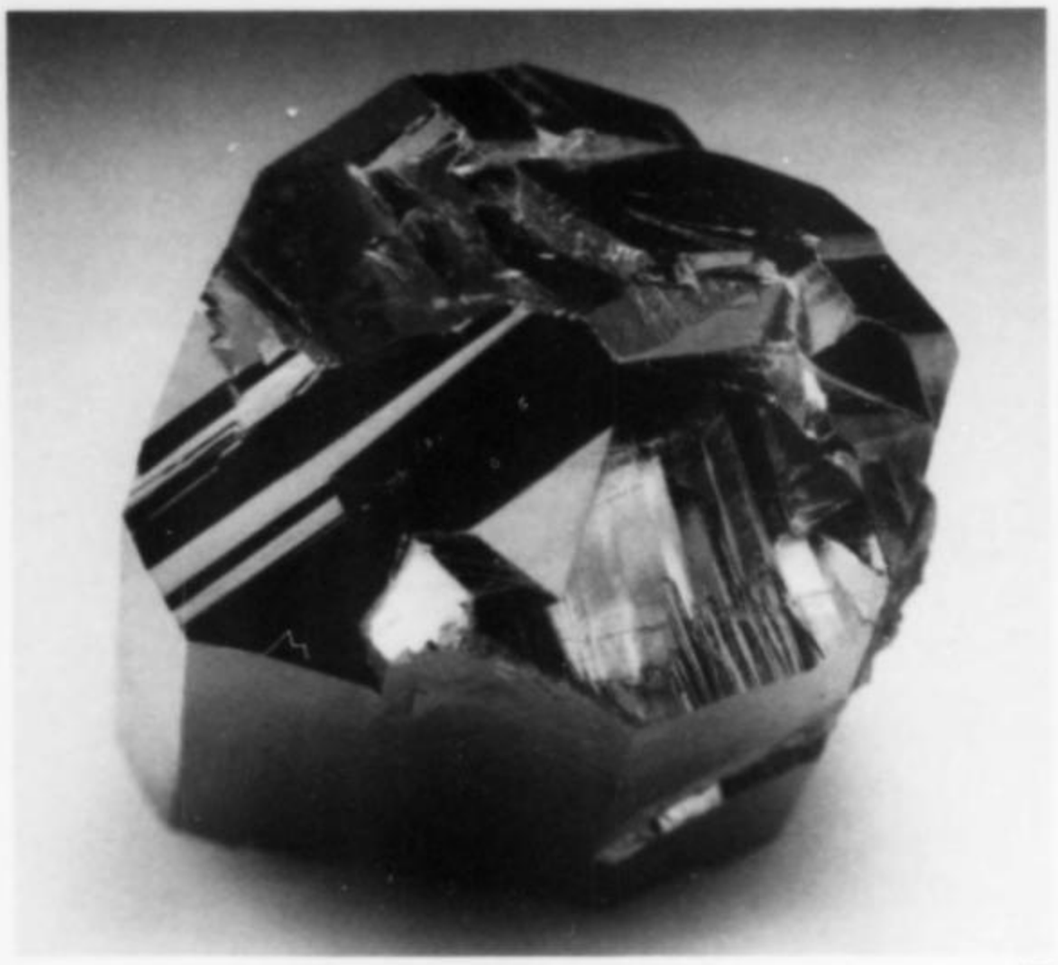


Figure 18. **Very large (10 cm), heavy, equant rutile crystal. James Fowler collection.**

(1976) shows that this rutile is characterized by 0.1% tin and 0.07% niobium. It is possible that substitution of these elements for titanium in the rutile structure encourages cyclic twinning.

Little was known about the actual paragenesis of rutile at Graves Mountain prior to the work of Hurst (1959). His geologic mapping showed that coarsely crystalline rutile occurred erratically throughout a poorly defined zone within the resistent kyanite quartzite that upheld the southwest summit. Weathering of rutile-rich zones related to pyrophyllitic alteration and veining, and quartz veins with bordering coarse-grained kyanite with abundant iron oxides, all from within this general zone, supplied the float specimens found prior to mining.

The occurrence of specimen rutile in the active mine is generally restricted to the immediate vicinity of late quartz veins. Occasionally quartz veins or lenses are found that contain lenticular cavities lined with crude quartz crystals, iron oxides and rutile. Most rutile of this occurrence is coated with iron oxides which can be removed with extreme care. Only rarely are cavities found in which both rutile and quartz are uncoated and lustrous. Other exceptional rutile crystals occur within what appears to be recrystallized and altered rock immediately adjacent to quartz veins. In this mode of occurrence the rutile crystals are generally forzen in coarsely crystalline kyanite or pyrophyllite. In general, the larger crystals are associated with the coarsely crystallized kyanite. Also found in massive white quartz veins are simple prismatic rutile crystals up to 8 cm in length. Usually these crystals are quite well developed but lack the brilliant luster of those occurring in cavities, pyrophyllite veins, or iron oxide–rich kyanite masses.

In addition to spectacular, coarsely crystalline rutile, minute red-brown rutile is common as an accessory mineral throughout the general zone of pyrophyllite veins and alteration. Individual grains are usually less than 0.1 mm in length and constitute less than 0.5% of the rock.

Sulfur S

Shepard (1859) mentions the presence of sulfur as occurring in tiny crystals with minute quartz crystals in cavities having the external shape of barite crystals. It is possible that at least a part of the

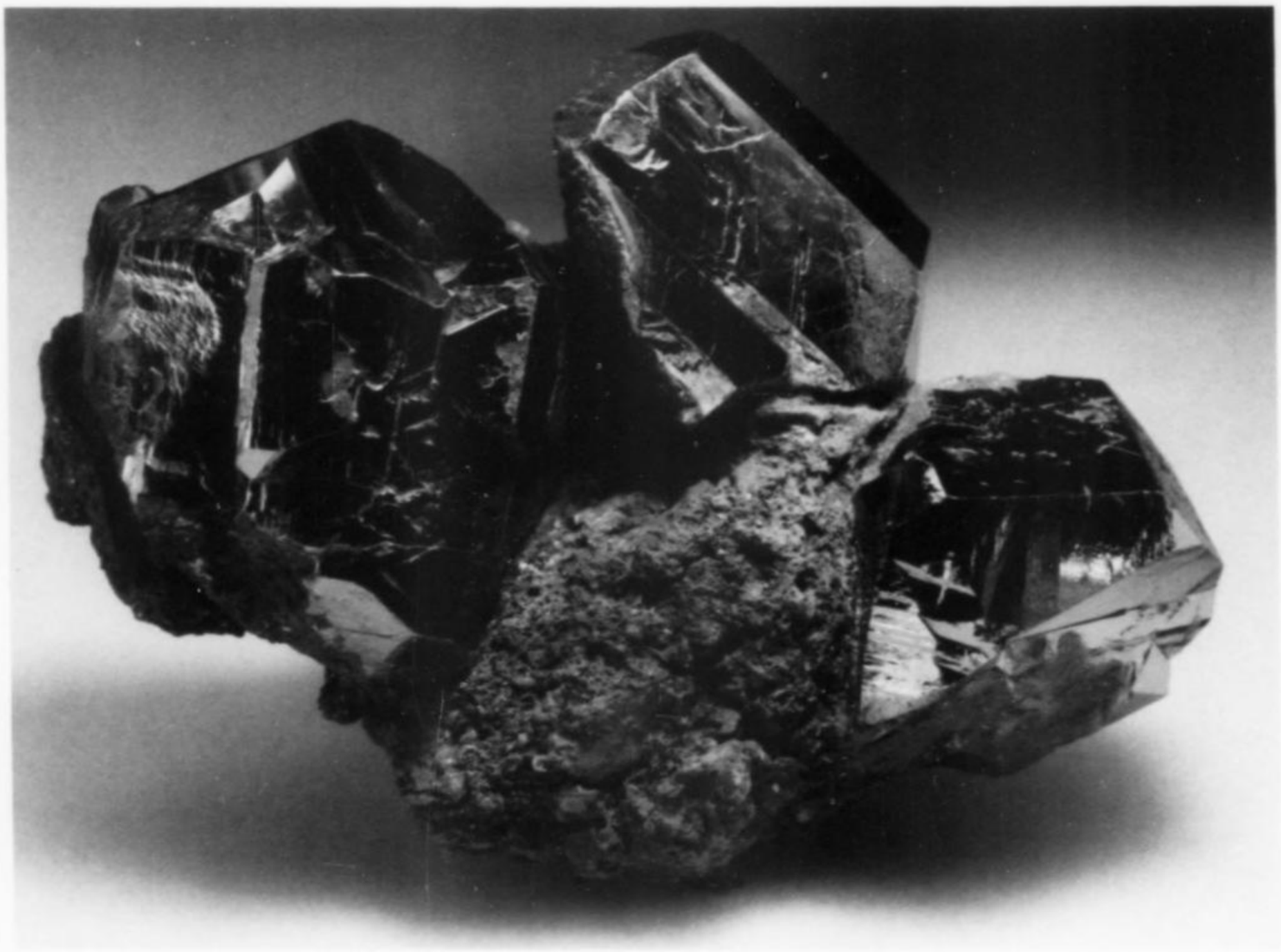


Figure 19. **Exceptionally large (17 cm) and heavy group of rutile crystals on matrix. James Fowler collection.**

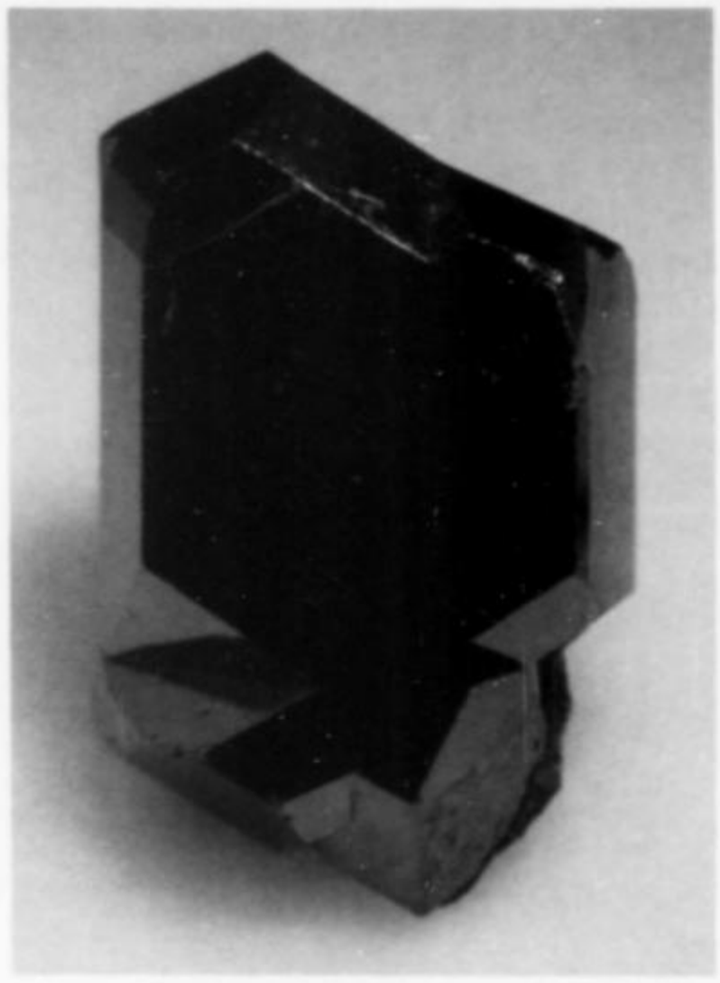


Figure 20. **Penetration twin of rutile, 6.8 cm. James Fowler collection.**

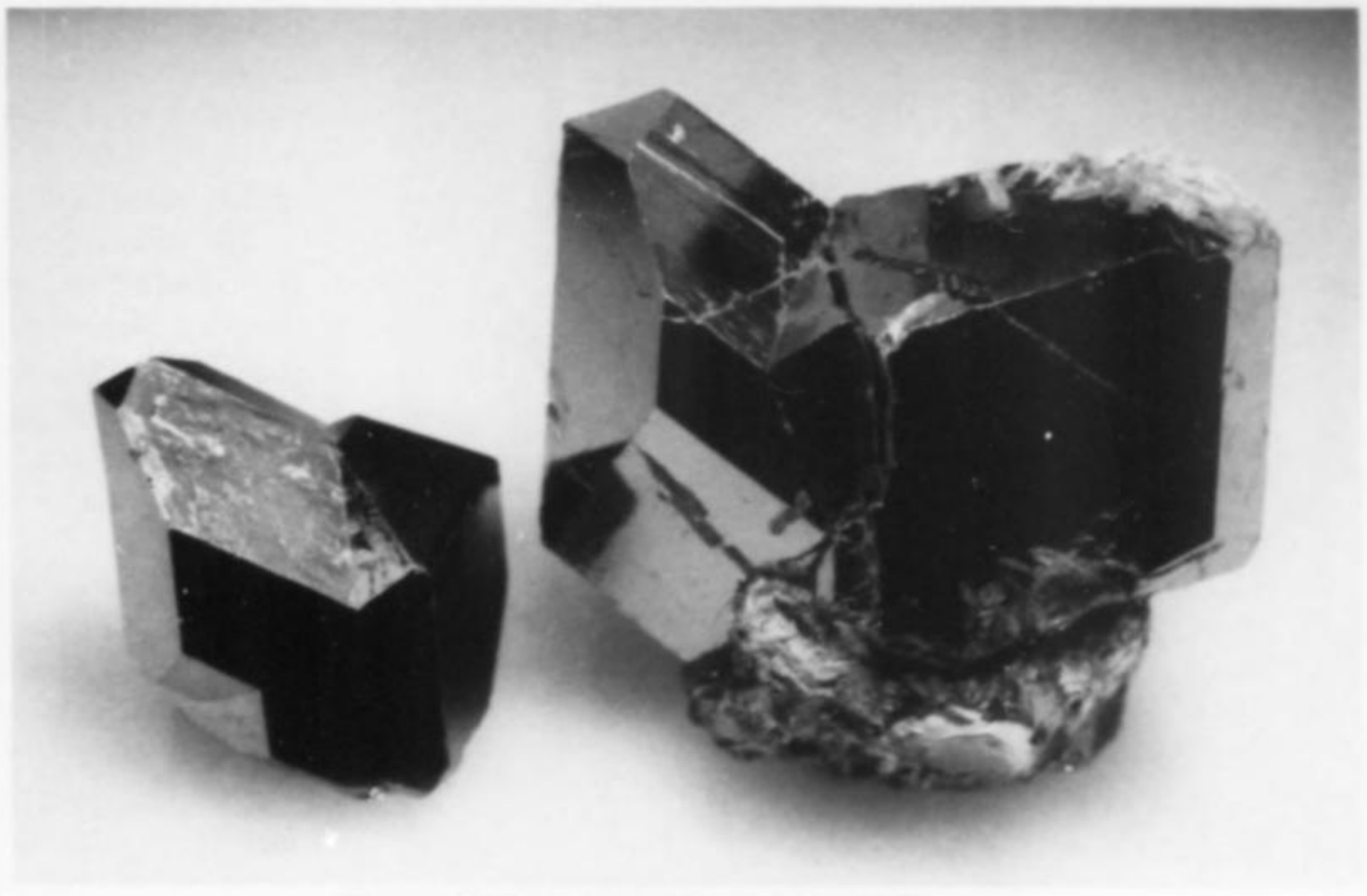


Figure 21. **Twinned rutile crystals, the large one measuring 5 cm. James Fowler collection.**

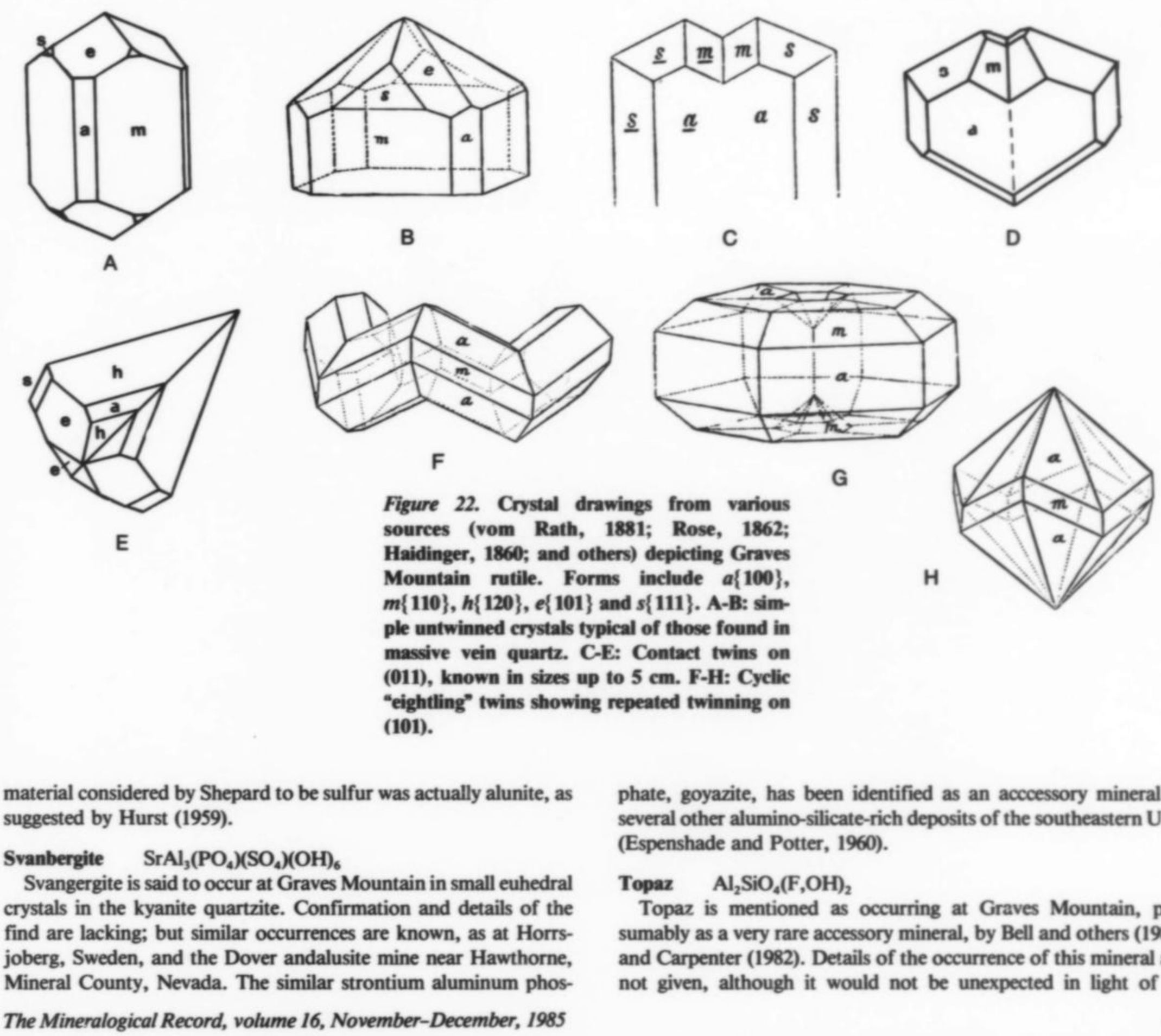


Figure 22. **Crystal drawings from various sources (vom Rath, 1881; Rose, 1862; Haidinger, 1860; and others) depicting Graves Mountain rutile. Forms include *a*{100}, *m*{110}, *h*{120}, *e*{101} and *s*{111}. A-B: simple untwinned crystals typical of those found in massive vein quartz. C-E: Contact twins on (011), known in sizes up to 5 cm. F-H: Cyclic "eightling" twins showing repeated twinning on (101).**

material considered by Shepard to be sulfur was actually alunite, as suggested by Hurst (1959).

Svanbergite $SrAl_3(PO_4)(SO_4)(OH)_6$

Svangergite is said to occur at Graves Mountain in small euhedral crystals in the kyanite quartzite. Confirmation and details of the find are lacking; but similar occurrences are known, as at Horrsjoberg, Sweden, and the Dover andalusite mine near Hawthorne, Mineral County, Nevada. The similar strontium aluminum phosphate, goyazite, has been identified as an acccessory mineral in several other alumino-silicate-rich deposits of the southeastern U.S. (Espenshade and Potter, 1960).

Topaz $Al_2SiO_4(F,OH)_2$

Topaz is mentioned as occurring at Graves Mountain, presumably as a very rare accessory mineral, by Bell and others (1980) and Carpenter (1982). Details of the occurrence of this mineral are not given, although it would not be unexpected in light of its

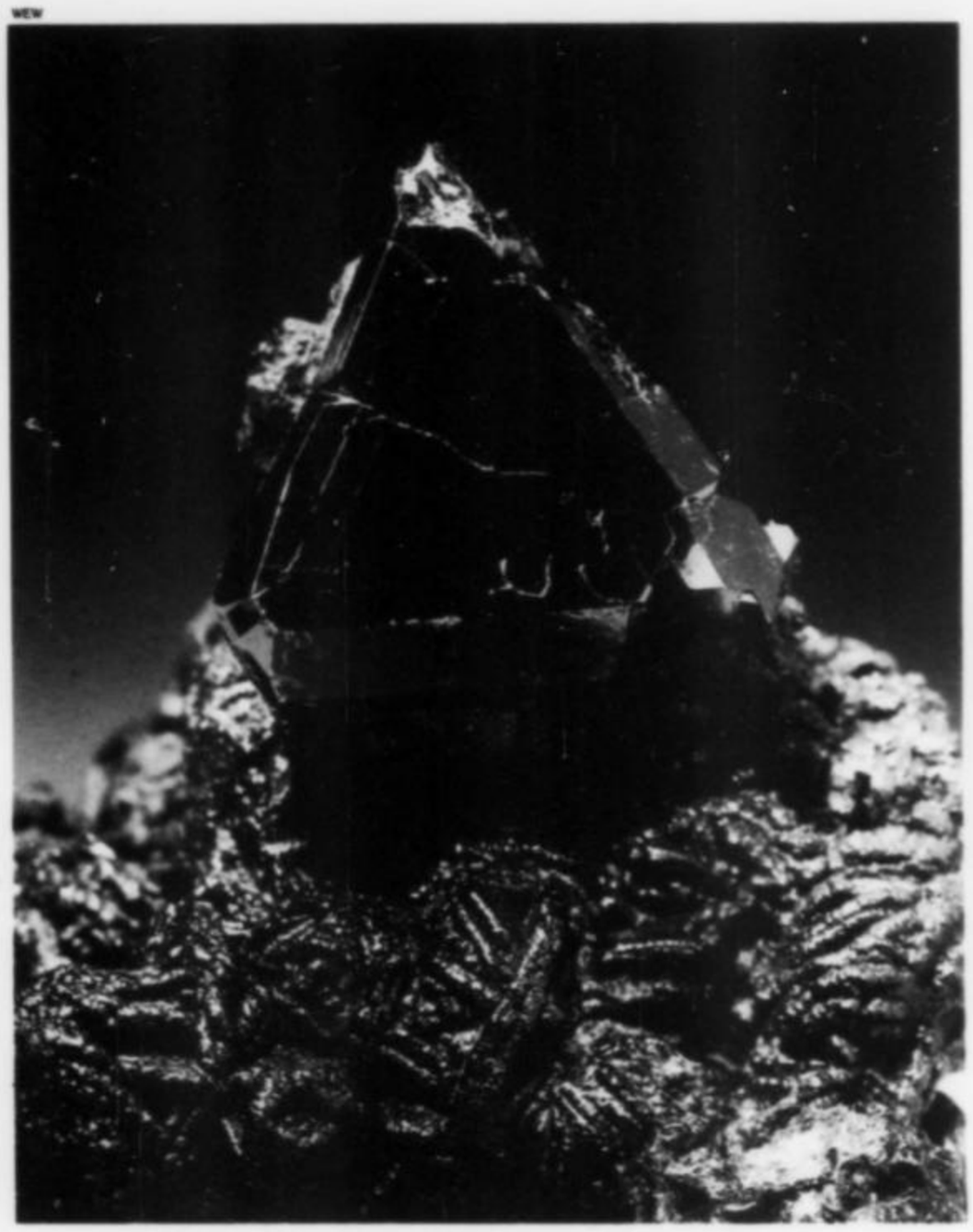


Figure 23. **Rare contact twin of triangular aspect; the crystal is 1.9 cm, on a matrix of iron oxide coated kyanite. James Fowler collection.**

presence in other aluminosilicate alteration assemblages of the Caroline Slate Belt, such as the well known Brewer, South Carolina, deposit (Pardee and others, 1937; Peyton and Lynch, 1953).

CONCLUSION

The Graves Mountain kyanite deposit is one of a series of aluminosilicate alteration zones related to volcanic activity in the Carolina Slate Belt island arc sequence and similar units of the southern Piedmont. It is mineralogically similar to occurrences farther to the northeast including Little Mountain and Henry Knob, South Carolina, and Clubb and Crowders Mountains, North

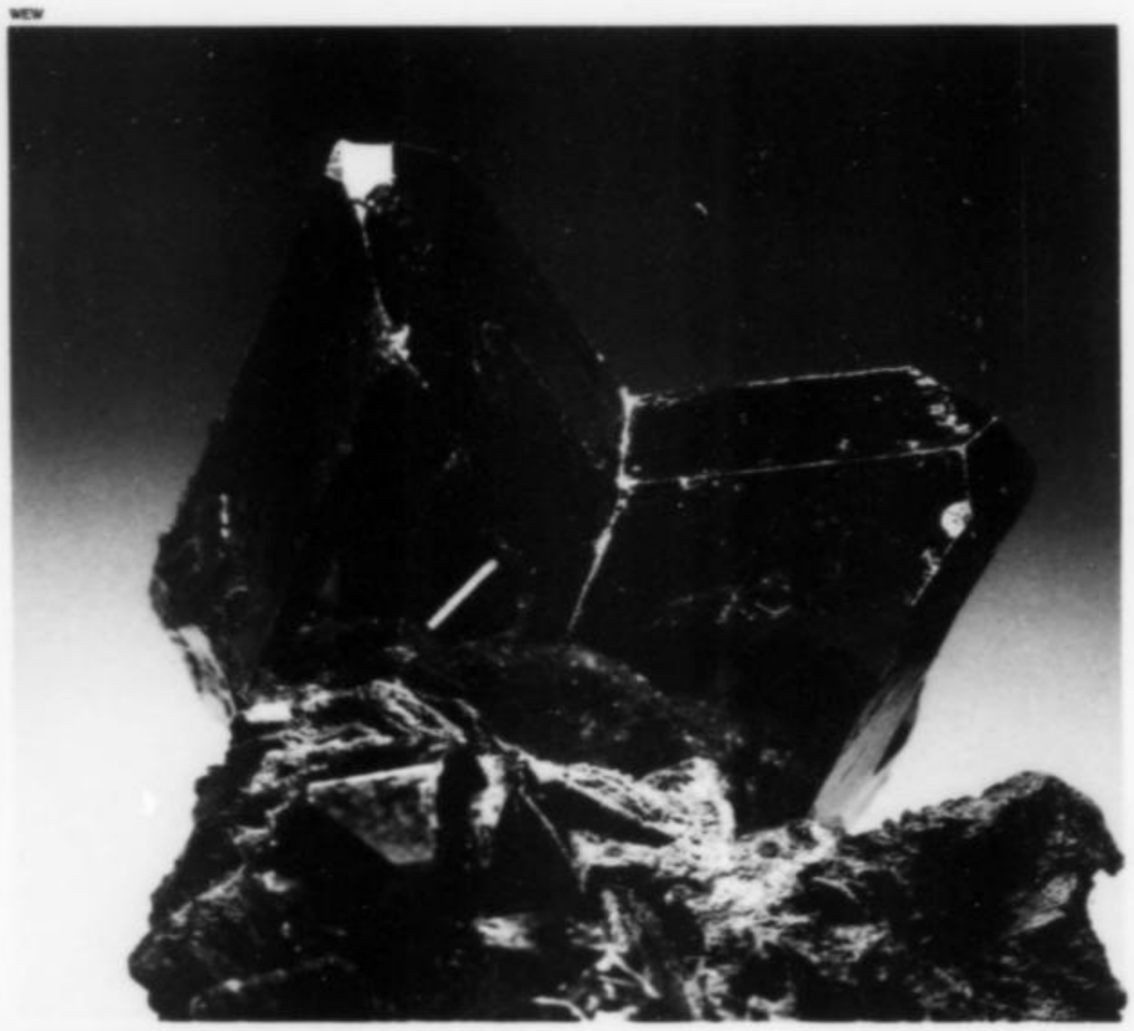


Figure 24. **Contact twin of a "fishtail" habit showing red internal reflections. The twin is 2.7 cm from point to point. James Fowler collection.**

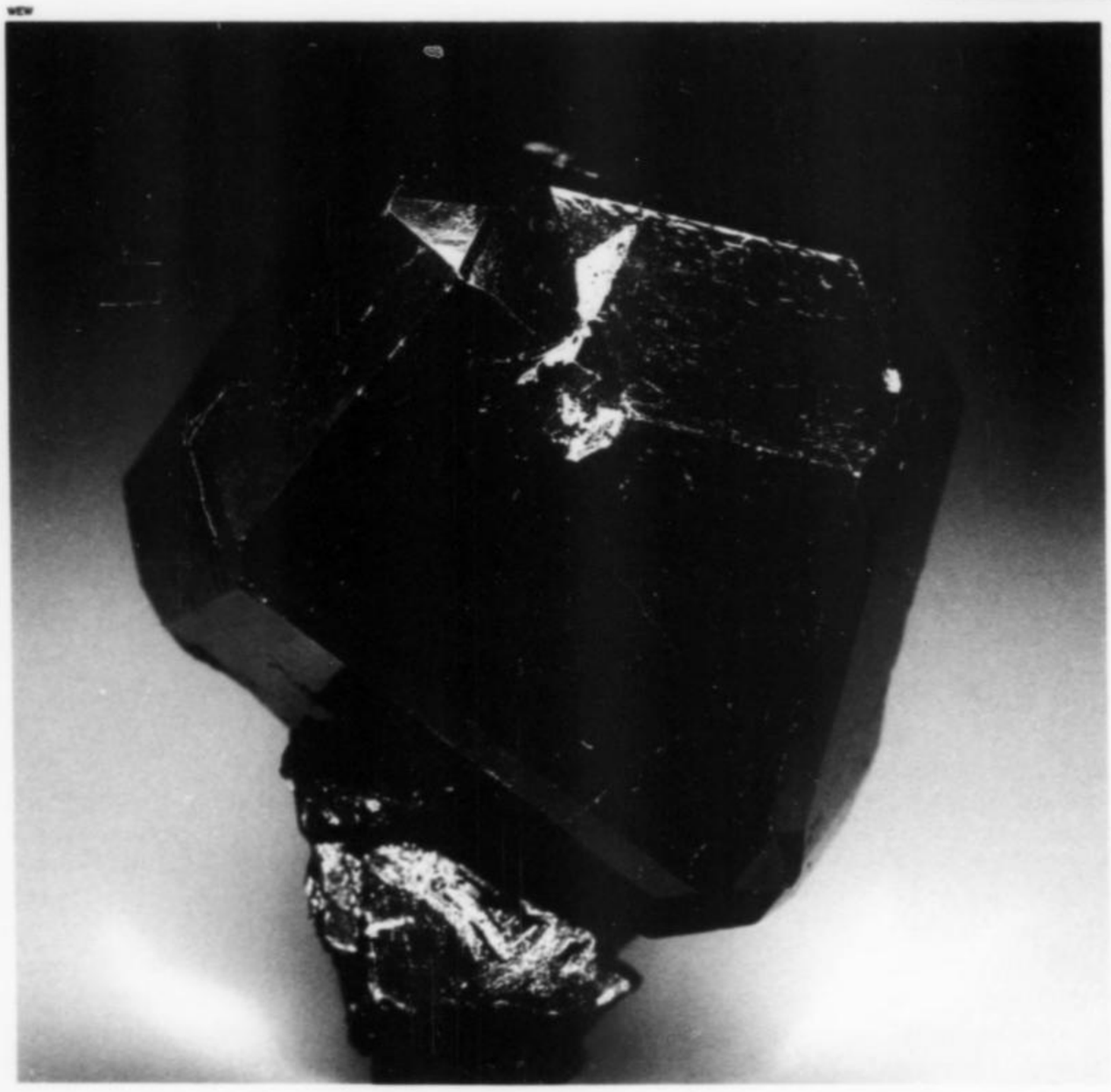


Figure 25. **Well-formed, blocky twin 3 cm across showing bright red internal reflections. James Fowler collection.**

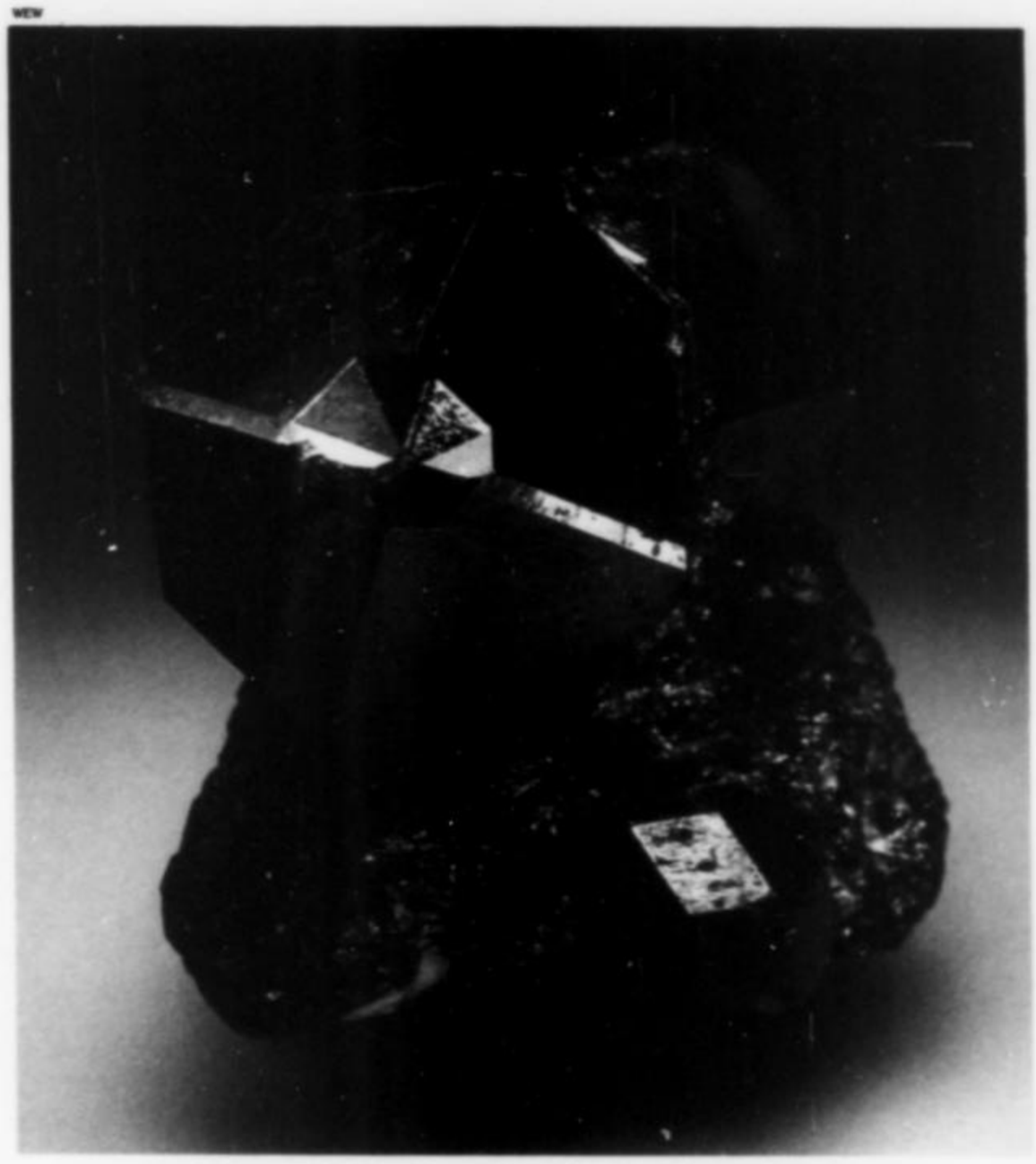


Figure 26. **Classic cyclic twin showing central re-entrant cavity; 3.2 cm across. David M. Crawford specimen.**

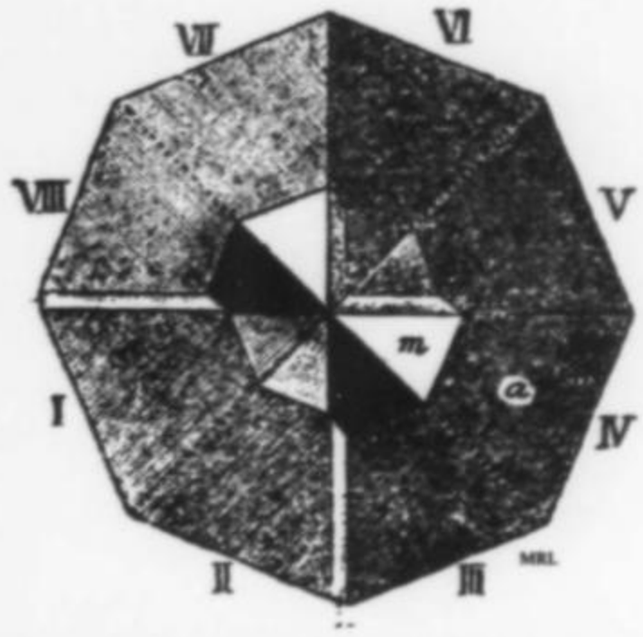


Figure 27. **Early illustration (Baumhauer, 1889) depicting the classic Graves Mountain cyclic twin.**

Figure 28. **Rutile crystal 5 cm long on iron oxide matrix. James Fowler collection.**

Figure 29. **Rutile crystal, 3.6 cm, on pale blue-green uncoated kyanite crystals. William Warren collection; photo by John Muntyan.**

Carolina. The sequence of events leading to the formation of the deposit is most likely similar to that proposed by Hartley (1976). While rutile, lazulite and pyrophyllite occur sparingly at many of the similar aluminosilicate monadnocks, none equal Graves Mountain in terms of quantity and quality. The exceptional mineralogical characteristics of Graves Mountain seem to be directly related to the intensity of relatively late phenomena including the development of quartz veins and pyrophyllitic alteration.

Graves Mountain, certainly one of America's classic localities, will likely continue to supply specimens of rutile, lazulite and pyrophyllite for some time to come. In addition, other species will be added to the present list of minerals known to occur there as more micromounters gain access to altered or weathered phosphate-rich rock. The deposit continues to be off limits to collecting, however, without written prior arrangement with the operator.

ACKNOWLEDGMENTS

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Hutchinsonite
from Quiruvilca, Peru

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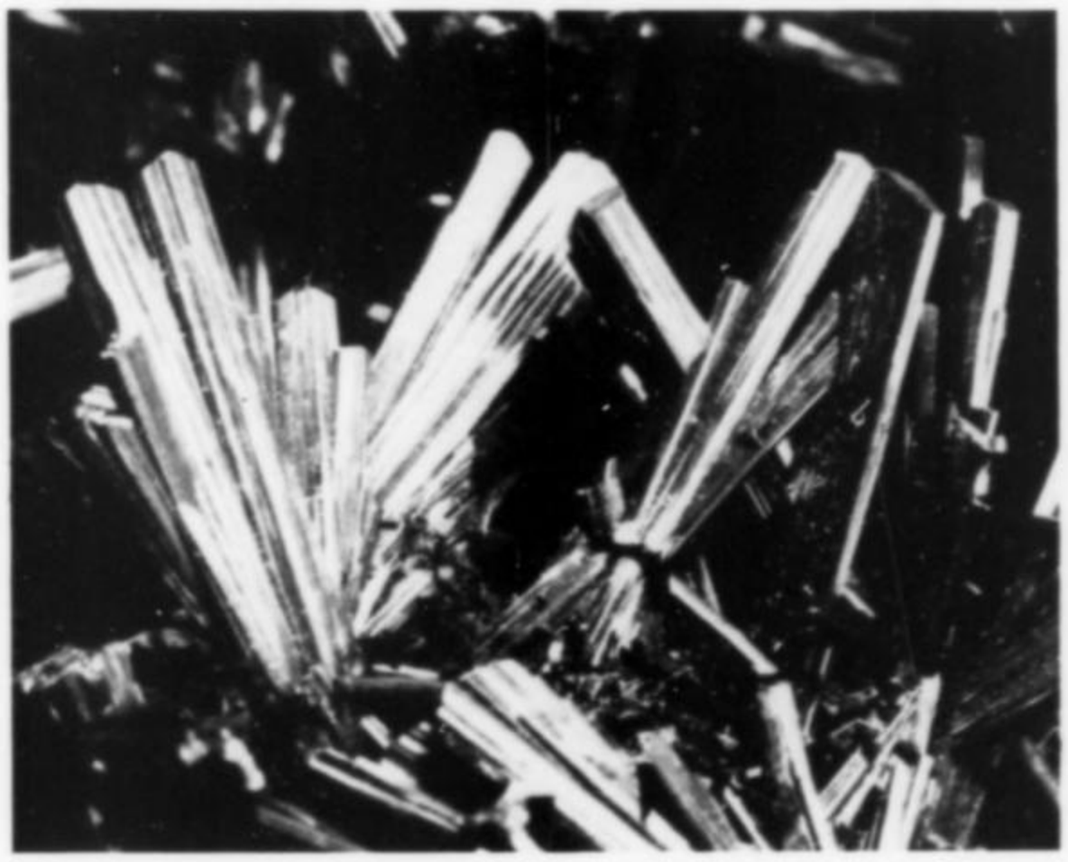
The Smithsonian Institution has just placed on exhibit an extraordinary specimen of the lead-thallium mineral hutchinsonite from the La Libertad mine, Quiruvilca, Peru. Hutchinsonite had been considered a relatively rare mineral until it began to appear at Quiruvilca in 1972, or even earlier. Little attention has been given to this remarkable occurrence save a short note published in the *Mineralogical Record* (Dunn, 1977). Prior to its discovery in Peru, hutchinsonite was known only in micro or near-micro crystals from its original locality of Lengenbach, in the Binnatal (or Binnental), Valais, Switzerland (Smith and Prior, 1907) and from the Segen Gottes lead-zinc mine near Wiesloch, Baden, West Germany (Seeliger, 1954). Reference was made in 1959 to a "possible occurrence" of hutchinsonite in sphalerite in the Soviet Union (*Chemical Abstracts,* **53**, 16,833), but has not, to the authors' knowledge, been substantiated. At Lengenbach it is found in dolomite associated with sphalerite, pyrite, realgar, orpiment, sartorite and other thallium minerals including rathite and hatchite. At Wiesloch it is associated with orpiment, galena, jordanite and sphalerite.



wcw

Figure 1. **Hutchinsonite crystals to 1 cm. Smithsonian collection.**

The earliest analyses of the mineral were reported by Smith and Prior (1907) on Lengenbach samples of 0.0184 and 0.0664 grams, respectively. These analyses were very good in view of the small sample size and when they were done (1907), except that the samples appear to have been contaminated by another phase containing silver, or both silver and copper. On the basis of these analyses the formula for hutchinsonite was first given as $(Pb,Tl)_2(Cu,Ag)As_5S_{10}$. More modern analyses by microprobe, also on Lengenbach material (Takéuchi *et al.,* 1965), clearly indicate that Cu and Ag are not essential constituents. Structural analysis by these authors produced a new formula: $(Pb,Tl)_2As_5S_9$.

Takéuchi *et al.* (1965) observed that "chemical analyses show that there are about the same numbers of Pb and Tl atoms in the unit cell" and "calculation of inter-atomic distances shows that the mean $(Tl,Pb)_{II}$-S distance is larger than the $(Pb,Tl)_I$-S distance, and also the temperature factor of the former is somewhat higher than that of the latter," but they stopped short of taking the position that Pb and Tl are completely ordered. They certainly recognized the likelihood, however, for they wrote "If we assume complete ordering by placing Pb at the $(Pb,Tl)_I$ site and Tl at the $(Tl,Pb)_{II}$ site, the *R* value for the *F*(*hk*0) data improves by 0.4%."

A new analysis on crystals from Peru is reported here and it indicates that the Pb and Tl contents are essentially the same, approximating a Pb:Tl ratio of 1:1. It seems apparent, therefore, that Pb and Tl are completely ordered, their relative amounts are ideally equal, and that the formula can be written $PbTlAs_5S_9$, rather than as above where Pb and Tl are placed within parentheses suggesting mutual substitution, which does not appear to occur. None of the five chemical analyses (Table 1) support the possibility of such substitution.

The Quiruvilca hutchinsonite is markedly superior to the Swiss and German occurrences. A reasonably large number of specimens appear to have been found at the La Libertad mine; the Smithsonian has eleven specimens. The newly exhibited specimen is exceptional; it measures 10 x 10 cm on the largest face and 2 cm in thickness. One surface is heavily populated with prismatic crystals of hutchinsonite, most of which are 1 cm or slightly more in length. Due to the much smaller size of the crystals from Lengenbach, the color of hutchinsonite has been described as varying between rich red and deep red with a brownish hue. The crystals from Peru are

so large that they appear silvery gray in color and have a submetallic to metallic luster. When viewed under magnification, however, flashes of red internal color may readily be seen and the powder color, of course, is a strong vermillion.

Associated with hutchinsonite on many of the specimens is beautifully crystallized orpiment, occurring most frequently in two different habits. Orpiment which is directly associated with hutchinsonite is usually in small, spherical groups of radially divergent crystals. These are deep orange in color on the surface, but mustard-yellow internally. Magnificent specimens of orpiment, not directly associated with hutchinsonite, in groups of large, well-defined crystals have also been recovered and these, too, appear to have been relatively abundant from this locality. Just as with the spherical clusters, these are a deep reddish orange in color on the surface and they are bright, submetallic, golden yellow on freshly exposed surfaces. Other minerals found on the same specimens include enargite, barite and pyrite.

Table 1. **Chemical analyses of hutchinsonite.**

	1	2	3	4	5	Ideal
Pb	12.5	16	18.92	17.3	19.3	19.28
Tl	25	18	21.03	20.0	17.3	19.02
Ag	9	2	0.11	–	0	–
Cu	–	3	0.96	–	0	–
Fe	–	0.5	–	–	0	–
As	30.5	29.5	31.66	36.8	31.1	34.85
Sb	–	2	–	–	1.9	–
S	26	26.5	27.32	26.5	29.3	26.85
	103.0	97.5	100.00	100.6	98.9	100.00%

1. Smith and Prior (1907) (sample size 0.0184 gm) – Lengenbach
2. Smith and Prior (1907) (sample size 0.0664 gm) – Lengenbach
3. Takéuchi *et al.* (1965) – Lengenbach
4. Takéuchi *et al.* (1965) – Lengenbach
5. J. A. Nelen – La Libertad mine, Quiruvilca, Peru. Analysis by electron microprobe. All results corrected by modified MAGIC correction program. The Pb amount may be slightly high due to overlap with Tl M_β peak. As no Tl standard was available, Pb intensities were used to measure Tl content (Specimen #135040). Some sulfur is probably present in substitution for arsenic.

The hutchinsonite from the La Libertad mine, Quiruvilca, Peru, unquestionably represents the ultimate in quality for the species. Very likely the same can be said for the orpiment from the same occurrence.

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new occurrences for
Ushkovite
and comments on laueite

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Ushkovite, $MgFe^{+3}_2(PO_4)_2(OH)_2 \cdot 8H_2O$, was recently described by Chesnokov *et al.* (1983) from the Il'men (Ilmen) Mountains, Soviet Union. It is a pegmatite phosphate and is the Mg-analog of laueite, $MnFe^{+3}_2(PO_4)_2(OH)_2 \cdot 8H_2O$.

An analytical survey of some phosphates by this writer included specimens of presumed laueite from classic localities such as the Palermo mine in New Hampshire; Sandamab, Namibia; and the Hagendorf pegmatites near Waidhaus in Bavaria, West Germany. The crystals analyzed were chosen by random selection; they exhibit no distinctive characteristics which would suggest they are not laueite. The crystals were examined by X-ray powder diffraction techniques and found to be in the laueite-ushkovite series.

The samples studied all proved to be ushkovite, close to the end member, and not laueite. The analytical data are presented in Table 1. Scanning electron photomicrographs of ushkovite crystals are shown in Figures 1, 2 and 3. Ushkovite resembles laueite in every respect; they are distinguished only with difficulty inasmuch as their X-ray powder diffraction patterns are extremely similar. The parageneses of these ushkovites parallel those of laueite; all are found as blocky triclinic crystals associated with other secondary phosphates, including stewartite.

The status of laueite is unaffected. Re-examination of a type crystal in the Harvard University collection indicates that it has Mn » Mg and is thus true laueite. Because laueite is frequently associated with stewartite, a mineral for which there exists little analytical data, further studies might ascertain whether or not the

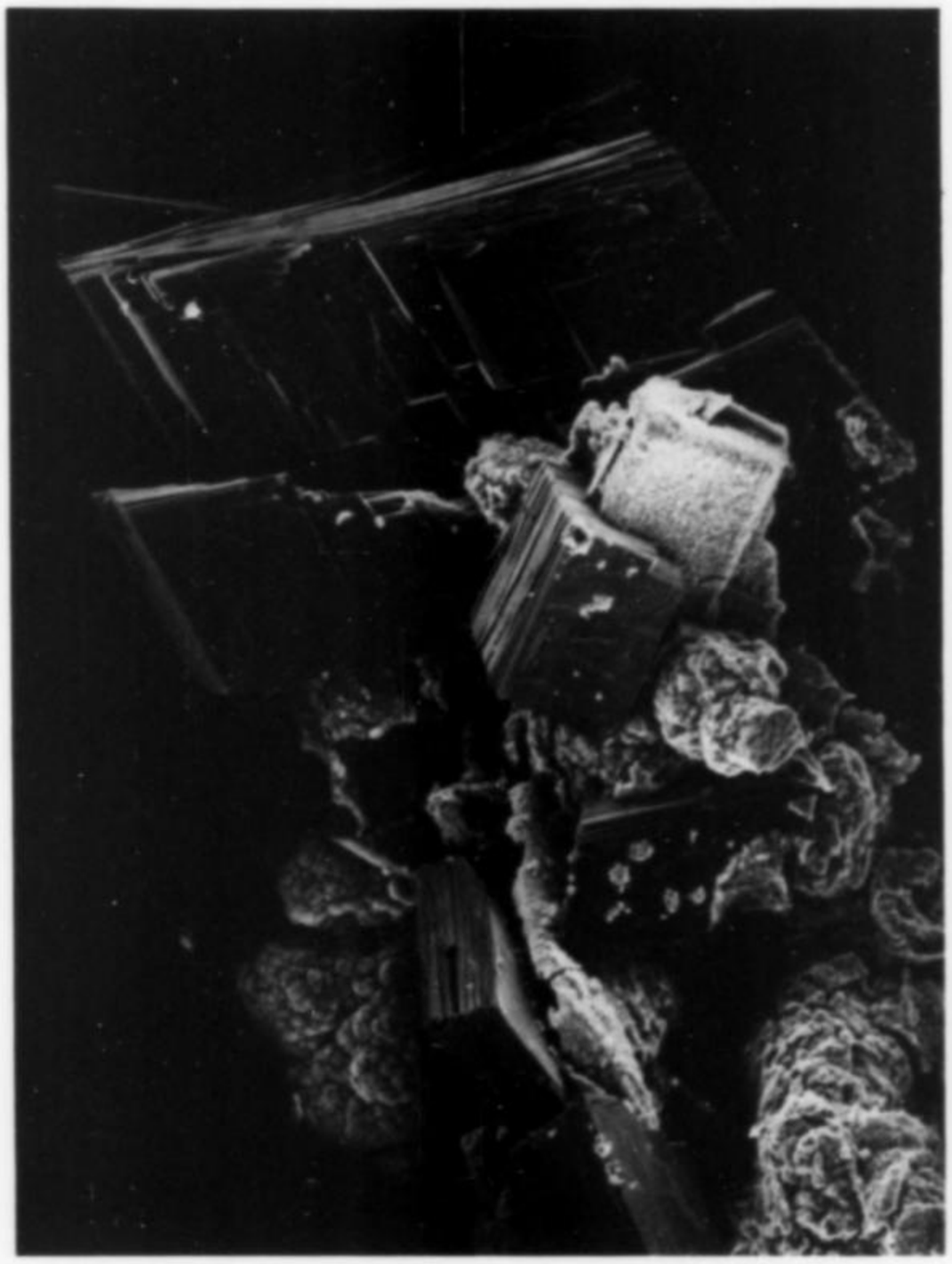

Figure 1. **Ushkovite from the Hagendorf pegmatites, Bavaria, Germany. NMNH 121370. Splintery edge at right is 280 microns.**

Figure 2. **Ushkovite from the Hagendorf pegmatites, Bavaria, Germany. NMNH 121370. Width of cluster is 600 microns.**

Figure 3. **Ushkovite from the Hagendorf pegmatites, Bavaria, Germany. NMNH 121370. Largest crystal is 200 microns on edge.**

Mg-analog of stewartite also exists, or whether the common association of "laueite with stewartite" reflects a preferential partitioning of Mg and Mn, inasmuch as some of the "laueite" in such associations is indeed ushkovite.

In light of a paucity of comparative data for well-studied specimens, the author does not wish to examine other possible ushkovites at this time.

***Table 1.* Microprobe analyses of ushkovites.**

Sample #	Al_2O_3	Fe_2O_3*	MgO	MnO	P_2O_5	H_2O**	Total	Locality
121370	0.1	31.8	8.1	0.2	28.2	31.6	100.0	Hagendorf
R9308	0.7	30.6	8.5	0.0	28.1	32.1	100.0	Palermo
148809	0.0	31.5	6.8	1.8	27.8	32.1	100.0	Sandamab
			Cations on the basis of P = 2					
121370	0.01	2.00	1.01	0.01	2.00			
R9308	0.07	1.94	1.07	0.00	2.00			
148809	0.00	2.01	0.86	0.13	2.00			

Microprobe analyses; operating conditions: 15 kV, 0.025 μA sample current, 20μ beam spot. Standards: maricite (Fe), montgomeryite (Al, P), manganite (Mn), hornblende (Mg).

*Total Fe calculated as Fe_2O_3

**H_2O by difference.

Accuracy of data: ±4% of the amount present.

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CHESNOKOV, B. V., VILISOV, V. A., CHEREPIVSKAYA, G. E., and GORSKAYA, M. G. (1983) Ushkovite, $MgFe_2^{+3}(PO_4)_2(OH)_2 \cdot 8H_2O$, a new mineral. *Zapiski Veseoyuznyi Mineralogicheskoe Obshchestva,* **112**, 42–46 (in Russian). (Abstract in *American Mineralogist,* **69**, 212–213).

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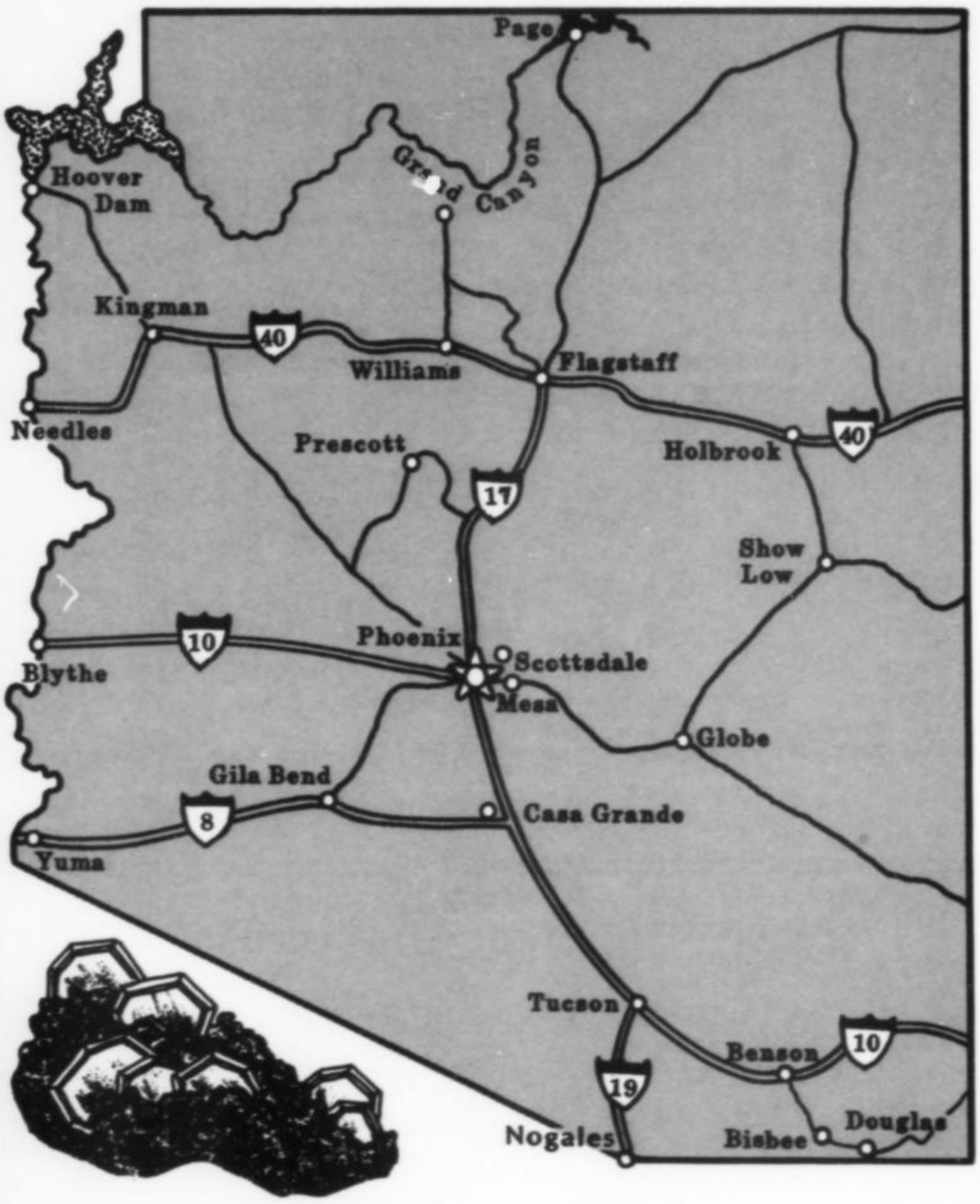

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Canaphite

a new sodium calcium phosphate hydrate from the Paterson area, New Jersey

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ABSTRACT

Canaphite, $CaNa_2H_2(PO_4)_2 \cdot 3H_2O$, is monoclinic, space group *Pa*, with unit cell parameters $a = 10.529(5)$, $b = 8.48(1)$, $c = 5.673(4)$Å, $\beta = 106.13(6)°$, $V = 486.4(9)$Å^3, $Z = 2$. Microprobe analysis yielded $Na_2O = 16.5$, $MgO = 0.2$, $CaO = 17.5$, $P_2O_5 = 43.4$, H_2O (by DTA-TGA) = 21.8, sum = 99.4 weight %, which corresponds to $CaNa_2H_2(PO_4)_2 \cdot 3H_2O$. Canaphite occurs as colorless, prismatic, lustrous, monoclinic crystals, elongate on [001], tabular on {010} and composed of the forms {010}, {001} and {100}. Physical properties include: density 2.24 g/cm^3 (2.27 calc.); hardness (Mohs) approximately 2; white streak; and perfect {010} cleavage. The strongest lines in the X-ray powder pattern are (*d*, I/Io, hkl): 8.47 *80* 010; 5.44 *80* 001; 4.36 *70* 210, $20\bar{1}$; 3.06 *100* $31\bar{1}$, 211; 2.608 *90* $32\bar{1}$. Canaphite occurs as clusters of colorless crystals coating stilbite, purportedly from Haledon, New Jersey. The name is for the chemical composition.

INTRODUCTION

The new species described herein was first noted by the late L. Neal Yedlin and preserved in his micromount collection as an unknown. His micromount collection was bequeathed to the Smithsonian Institution and, during the curation of this collection, the crystals we describe were called to our attention by Herbert Corbett. Because the prismatic, well-formed crystals have a unique appearance, and because they had not previously been observed by us in examination of zeolite assemblages, we initially suspected that this might be a new species. We therefore obtained X-ray powder diffraction data and a qualitative microprobe analysis; these preliminary investigations confirmed that it is a new species and our subsequent study has validated this observation and led to its characterization.

The new phase is named *canaphite* in allusion to the chemical composition, calcium sodium hydrogen phosphate. The new mineral and the name were approved prior to publication by the Commission on New Minerals and Mineral Names, I.M.A. Type material is preserved in the Smithsonian Institution under catalog #160286.

CRYSTALLOGRAPHY

Morphology

Canaphite occurs only as lustrous, euhedral, prismatic crystals elongate on [001] and tabular on {010}. The forms present are {010}, {100} and {001} with {010} dominant. Individual crystals are up to 0.5 mm long. A representative cluster of canaphite crystals is shown in Figure 1.

X-ray crystallography

Crystals were studied using Weissenberg and precession techniques which showed that canaphite is monoclinic with extinctions consistent with space groups *Pa* or *P2/a*. Three-dimensional intensity data were measured in preparation for a crystal-structure analysis. These were analyzed for centrosymmetry using the N(Z) test, showing that canaphite is acentric and therefore has space group *Pa* (R. L. Freed, personal communication). Powder X-ray diffraction data are given in Table 1. They were obtained using a 114.6-mm diameter Gandolfi camera, CuKα radiation, Si as an internal standard, and a polycrystalline specimen. The lattice parameters were refined using these data, and are: $a = 10.529(5)$Å, $b = 8.48(1)$Å, $c = 5.673(4)$Å, $\beta = 106.13(6)°$.

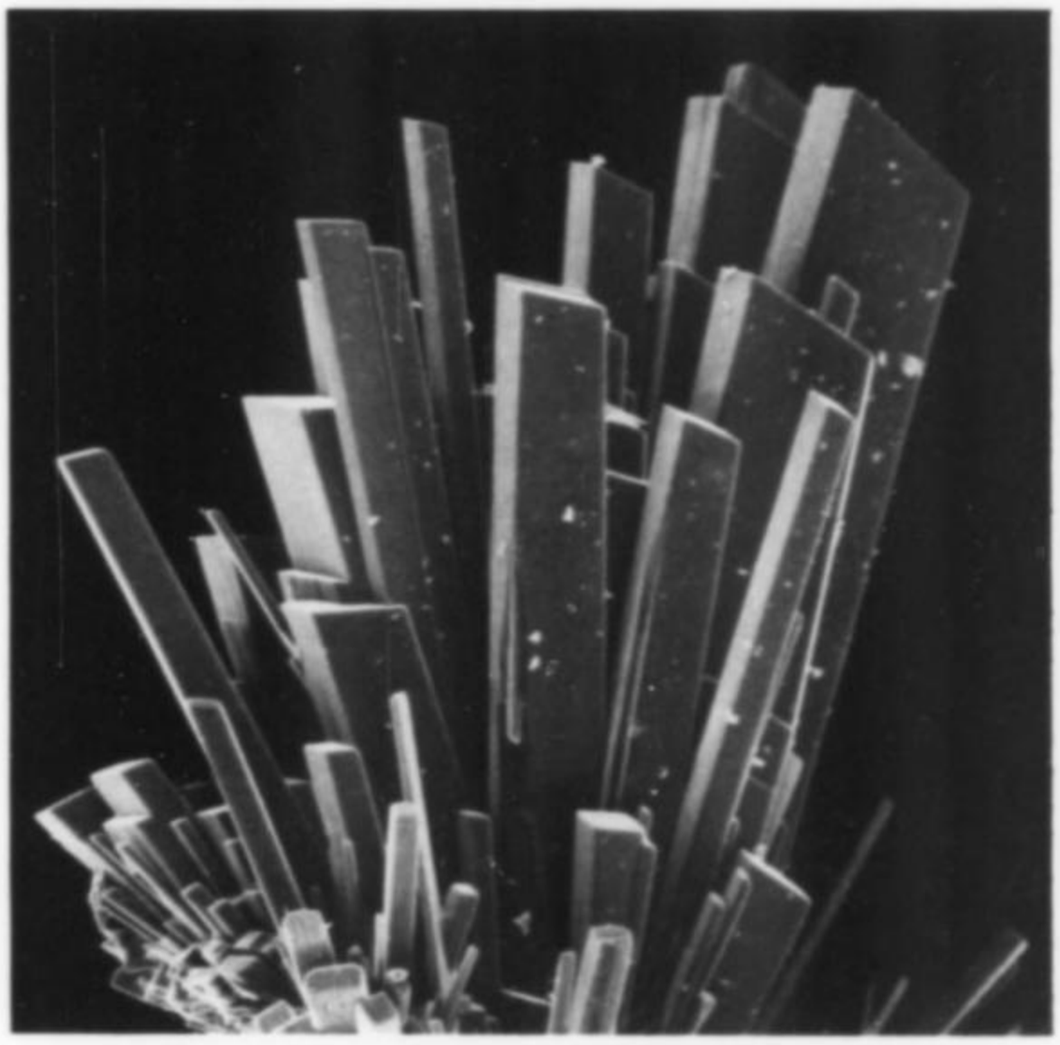

Figure 1. **Radiating cluster of canaphite crystals exhibiting typical morphology for this species. The largest crystal is approximately 100 μm in width.**

CHEMISTRY

Canaphite was chemically analyzed using an ARL-SEMQ electron microprobe utilizing an operating voltage of 15 kV and a sample current of 0.025 μA, measured on brass. The standards used were montgomeryite (Ca, Mg, P) and maricite (Na). A wavelength-dispersive microprobe scan indicated the absence of any elements with atomic number greater than 9, except those reported herein. Water was determined by DTA-TGA, which indicated a total H_2O content of 21.8 weight %. The resultant combined analysis yields $Na_2O = 16.5$, $MgO = 0.2$, $CaO = 17.5$, $P_2O_5 = 43.4$, $H_2O = 21.8$, total = 99.4 weight %. Unit cell contents, calculated using the unit cell parameters and the observed density, yield $Ca_{2.05}Na_{3.49}Mg_{0.03}H_{4.39}(PO_4)_{4.01} \cdot 5.73H_2O$, or ideally, $CaNa_2H_2(PO_4)_2 \cdot 3H_2O$ with $Z = 2$.

Special care was taken to measure water using a Mettler TAI thermoanalyzer equipped with an Inficon IQ 200 quadrapole mass spectrometer for the determination of gases evolved during heating. The sample lost 4.2 weight % during the 3 hour period prior to analysis in which the instrument was pumped down and the vacuum established. During this period the temperature was 21° C and the pressure was reduced from approximately $1x10^{-3}$ to $1x10^{-7}$ torr. At the end of the 3 hours the sample was still losing weight at a rate of 0.7 weight % per hour when the analytical run was initiated. A water loss of 17.6 weight % was identified by mass spectrometer, occurring between 80° and 430° C. This was composed of a major loss with a maximum rate of loss at 200° C and a smaller loss with a maximum rate of loss at 310° C. The total water loss was 21.8 ± 1.0 weight %, and no direct loss of H_2 was observed. Between 800° and 1445° C the sample lost a further 47.2 weight % and melted, but O_2 and minor CO_2 were the only evolved gases that could be identified with the mass spectrometer.

The loss of 4.2 weight % water under vacuum represents 0.75 H_2O per formula and suggests that some of the water is fairly loosely bound in the canaphite structure. The two-stage water loss between 80° and 430° C is difficult to interpret because there is a considerable overlap between the two events; however the approximate ratio of the two peaks is 5.5:1. This represents approximate losses of 2.75 H_2O followed by 0.5 H_2O per formula. The large loss near the end of the thermogram was associated with melting of the sample and was produced by oxygen and the boiling off of unknown elements that were deposited on the walls of the vacuum column as the temperature decreased along the path to the spectrometer.

PHYSICAL AND OPTICAL PROPERTIES

Canaphite is colorless and transparent. The hardness could not be measured precisely, but is approximately 2 (Mohs). The density, determined using heavy liquid techniques, is 2.24 g/cm³ (2.27 g/cm³ calc.); luster is vitreous on cleavage and fracture surfaces. There is an {010} cleavage which is perfect and easily produced; two other poor cleavages having the apparent indices {100} and {001} were observed in crushed fragments using the optical microscope. There is no fluorescence in either longwave or shortwave ultraviolet radiation.

Optically, canaphite is biaxial (−), with indices of refraction $\alpha = 1.496(2)$, $\beta = 1.504(2)$, $\gamma = 1.506(4)$; $2V = 52(5)°$, (52.9° calc.), in sodium light. There is no pleochroism. Orientation is $Z = b$, $X \Lambda c = 25°$. No dispersion is discernible.

OCCURRENCE

We have no direct evidence of the precise geologic occurrence of canaphite. The mineral was found on specimens of stilbite in the mineral collection of the late L. Neal Yedlin, which were labeled "*Haledon, N.J. 8-19-66*" in his handwriting. There is no attached rock matrix. The stilbite rests on quartz.

This quartz has numerous rectangular cavities, quite similar to those found in other samples from the Watchung Mountains. Similar molds have been attributed to pre-existing anhydrite and glauberite by Schaller (1932) and further discussion was provided by Peters and Peters (1978). These molds lend further credence to the attribution of at least the general locality to the Paterson area. Hence, the only available evidence for the type locality is that gleaned from Mr. Yedlin's notations. Inasmuch as he was a careful collector, noted for taking pains with attribution of provenance, there is a high probability that the locality given is correct.

Haledon, New Jersey, is in the Watchung Mountains of northern New Jersey. The most likely site within Haledon is Braen's quarry where minerals have been collected in recent years. The quarries in the local Triassic traprocks are noted localities for zeolites and the occurrence of stilbite in the area is expected. For a review of the minerals found in the local quarries, the reader is referred to Peters and Peters (1978).

Table 1. **Powder diffraction data for canaphite.**

I/I$_o$	d(Obs)	d(Calc)	hkl	I/I$_o$	d(Obs)
80	8.47	8.48	010	10	1.927
20	6.49	6.50	110	5	1.897
80	5.44	5.45	001	5	1.877
60	5.06	5.06	200	1	1.840
40	4.60	4.60	$11\bar{1}$	10	1.784
		4.58	011		
70	4.36	4.36	$20\bar{1}$	10	1.725
		4.34	210	5	1.715
40	3.94	3.91	120	40	1.688
60	3.87	3.88	$21\bar{1}$	10	1.659
		3.85	111	10	1.640
40	3.38	3.35	121		
		3.35	021		
60	3.28	3.28	201		
				5	1.600
100	3.06	3.06	211	5	1.573
		3.08	$31\bar{1}$	10	1.535
60	2.748	2.737	$20\bar{2}$	5	1.525
2	2.691	2.690	$11\bar{2}$	2	1.496
90	2.608	2.608	$32\bar{1}$		
20	2.529	2.529	400	2	1.474
30	2.482	2.472	$41\bar{1}$	5	1.454
5	2 462	2.467	230	2	1.439
40	2.387	2.383	$31\bar{2}$	10	1.421
30	2.307	2.299	$22\bar{2}$	5	1.403
20	2.207	2.206	$42\bar{1}$	10	1.382
20	2.161	2.161	202	2	1.320
30	2.097	2.094	212	10	1.269
20	1.998	1.002	$13\bar{2}$		
5	1.975	1.976	$14\bar{1}$		
		1.975	041		

ACKNOWLEDGMENTS

The authors are indebted to Robert Ramik of the Royal Ontario Museum for obtaining the DTA-TGA analysis, and to Thomas A. Peters for helpful discussions concerning the locality. We take special note of the contribution of the late L. Neal Yedlin (1908–1977) in recognizing the uniqueness of this mineral and in preserving it for subsequent investigations, and of Herbert Corbett for calling it to our attention.

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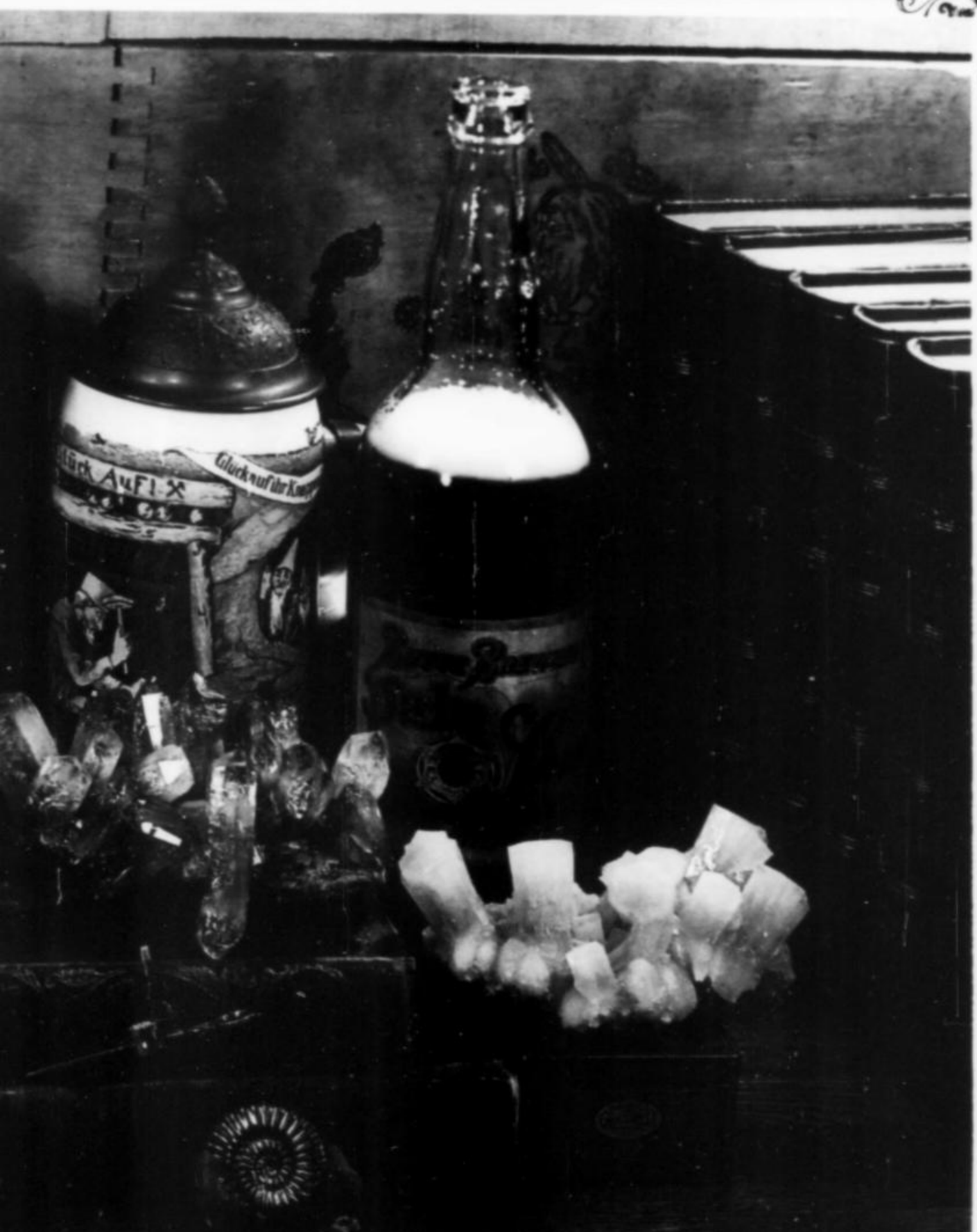
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DESIGN BY WENDELL E. WILSON

Calcioferrite

from the Moculta quarry near Angaston South Australia

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Exceptionally fine, bright greenish yellow microcrystals of the extremely rare phosphate mineral calcioferrite have been found at the Moculta quarry, South Australia, in association with apatite, jarosite and, more rarely, cacoxenite. This is the second known world occurrence for the mineral.

INTRODUCTION

Calcioferrite is an exceedingly rare phosphate mineral, first found as foliated, nodular or reniform masses of yellow crystals in a bed of Tertiary clay at Battenberg in Rhenish Bavaria (Blum, 1858, quoted in Palache *et al.,* 1951). The authors have been unable to find reference to any other localities for this mineral in the literature, although a specimen labeled calcioferrite from Bruges (or Begues), Barcelona, Spain, resides in the Smithsonian collection, Washington, D.C. The authenticity of this specimen has not been confirmed by chemical analysis (Pete J. Dunn, personal communication). Similarly, specimens labeled calcioferrite from Brugdes and Brueges, Barcelona, Spain, and from the Foote Mineral Company mine, Kings Mountain, North Carolina, are found in the collection of the Royal Ontario Museum, Toronto, Ontario, Canada, but their identity has not been confirmed (Joseph A. Mandarino, personal communication).

It has been proposed, on the basis of its X-ray powder diffraction pattern and a recalculation of its chemical formula, that calcioferrite may be the Fe^{+3} analog of montgomeryite (Dunn *et al.,* 1983). Similarly, calcioferrite is listed as an isotype of montgomeryite by Ramdohr and Strunz (1978), and has been so described by Mead and Mrose (1968) on the basis of analyses and an X-ray powder pattern.

LOCALITY

The Moculta quarry is one of several in the Angaston-Kapunda area of South Australia, all of which have been operated as sources of industrial phosphate. These deposits were discovered in 1882, recognized as phosphate deposits in 1903, and have been worked intermittently for phosphate from that time.

The Moculta quarry is located some 6 kilometers northeast of Angaston in Sections 102 and 105, hundred of Moorooroo. The deposit is situated within the area of the basal Cambrian lower levels of the Normanville group of limestones and marbles, and is closely associated with decomposed, ferruginous schist. The phosphate rock in the quarry occurs in clay and is found as small fragments, masses, mammilary structures and incrustations showing a fibrous structure. It occurs as white, granular, chalky material, as well as in yellowish, green, brown or pale bluish-gray masses up to several tons in weight.

The area where the calcioferrite was found lies in the northeast portion of the quarry. The exposure was some 3 meters in length and 1 meter in height, but a small portion had already been removed by quarrying operations at the time of discovery. Passing from south to north through this zone, altered pyrite together with jarosite, cacoxenite and tinticite were first encountered. Next, apatite, apatite with calcioferrite, and finally calcioferrite alone were observed. Where apatite and calcioferrite are found in the same vug, the former is found on and also supporting the latter. Hence, it appears that they are roughly contemporaneous.

The bulk of the phosphate ore lies in a large body through the central part of the quarry and immediately to the west of the jarosite outcrop. Phosphate minerals found there include aldermanite, beraunite, childrenite, crandallite, cyrilovite, dufrenite, fluellite, gorceixite, leucophosphite, minyulite, rockbridgeite, strengite, variscite, wavellite, and the aforementioned apatite, cacoxenite, montgomeryite and tinticite.

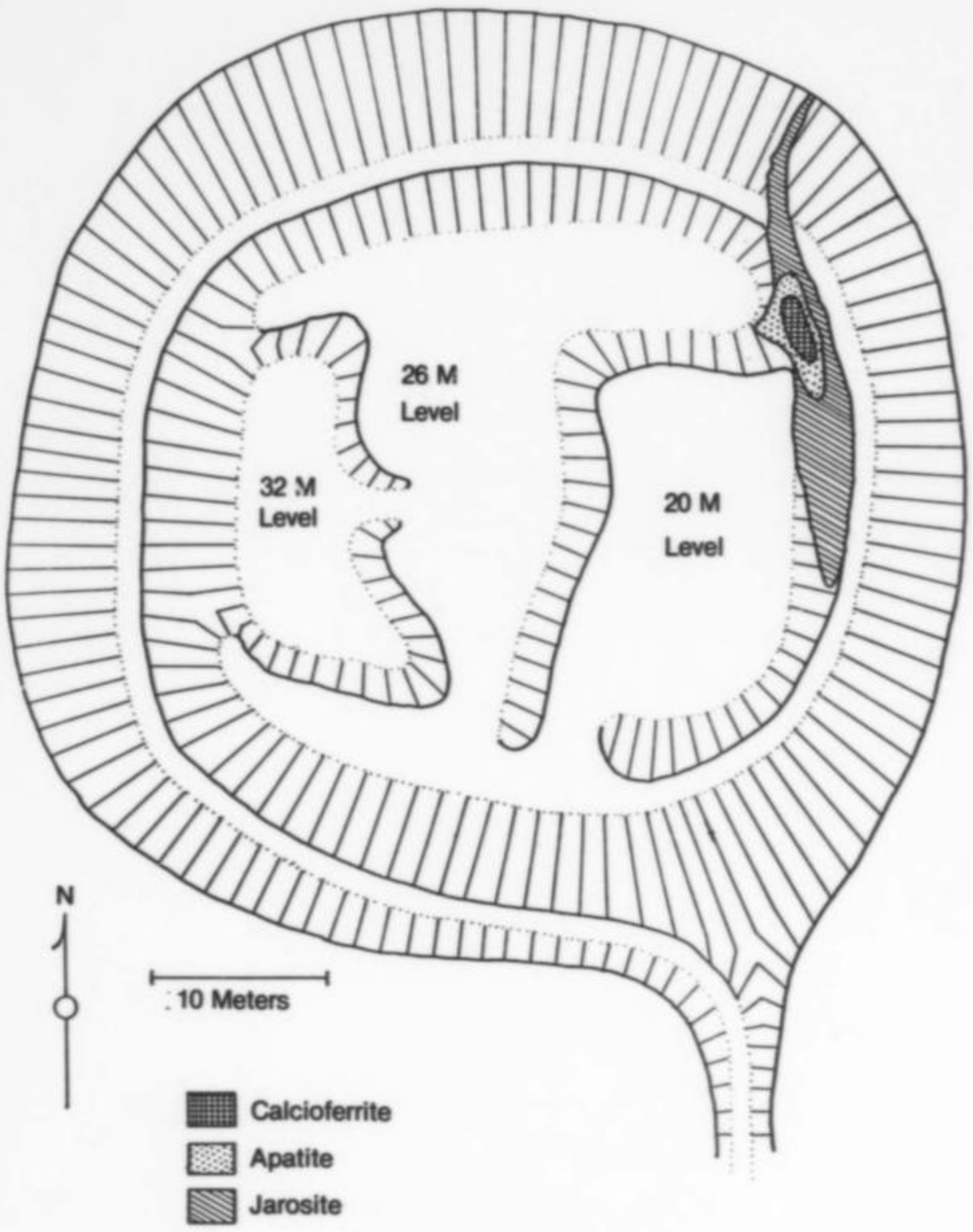

Figure 1. **Sketch map of the Moculta quarry, South Australia, showing the location of the calcioferrite occurrence.**

Figure 2. **North wall of the Moculta quarry. The dark area behind the truck is the main phosphate orebody. Immediately to the right and at the junction with the lighter colored rock is the jarosite body in which the calcioferrite was found.**

PHYSICAL DESCRIPTION

The calcioferrite occurs in vugs and tiny cavities in a highly altered, pale brown matrix which is apparently ferruginous and contains a high proportion of clay minerals. The vugs range in size from 1 to 10 mm. Crystals of calcioferrite are commonly found up to 0.5 mm in length and very rarely up to 2.0 mm, usually scattered in irregular to radiating groups on the vug walls. In some cases the calcioferrite is so profuse as to form continuous druses, and very rarely it is found in what appear to be single crystals.

Isolated crystals and those projecting from groups tend to be transparent, while aggregates are opaque. The color varies, even within a single hand specimen, from bright greenish yellow through yellow to opaque whitish yellow and off-white.

Crystals of calcioferrite (see Figs. 3 to 6 and the crystal sketch in Fig. 7) bear a remarkable resemblance to those of montgomeryite. The only significant difference is that the calcioferrite habit shows equal development in the *c* and *a* directions, while montgomeryite is usually elongated parallel to *c* (Larson, 1940; Dunn *et al.,* 1983). Larsen observed that montgomeryite is monoclinic, always lath-shaped, flattened on (010) and elongated parallel to [001]. He observed pyramidal terminations and prism faces, but the extreme thinness of the crystals and multiple reflections parallel to [001] made identification of the faces very difficult. All these observations apply equally well to calcioferrite. Rough goniometric measurements indicate that the β angle of calcioferrite is approximately 91.5°, compared with the β angle of 91° 34' reported by Larsen for montgomeryite. Calcioferrite shows pyramidal and prism faces as does montgomeryite, but these have not been identified.

CRYSTALLOGRAPHY and CHEMISTRY

The X-ray powder data for calcioferrite from the Moculta quarry is essentially identical to that of material from the type locality. It is also very similar to that of montgomeryite (Pete J. Dunn, personal communication).

The calcioferrite was analyzed by Pete J. Dunn using an ARL-SEMQ electron microprobe with an operating voltage of 15 kV and a sample current of 0.025 μA. The data were corrected using standard Bence-Albee factors. The standards used were montgomeryite (Ca, Mg, Al, P) and hornblende (Fe).

The average composition of crystals analyzed is $Al_2O_3 = 6.8$, $Fe_2O_3 = 15.4$, $MgO = 3.2$, $CaO = 17.8$, $P_2O_5 = 34.8$, with $H_2O = 22.0$ by difference, sum = 100.0%. The formula calculated from the above on the basis of 6 phosphorus atoms, together with the formulas for calcioferrite from Battenberg and for montgomeryite from the Tip Top mine, South Dakota (both from Dunn *et al.,* 1983) are given below.

Calcioferrite, Moculta quarry:

$Ca_{3.88}Mg_{0.97}(Fe^{+3}_{2.36}Al_{1.63})_{\Sigma 3.99}(PO_4)_6(OH)_{3.67} \cdot 13.11H_2O$

Calcioferrite, Battenberg:

$(Ca_{3.31}Fe_{0.36})(Mg_{0.83}Fe_{0.17})(Fe^{+3}_{3.29}Al_{0.71})_{\Sigma 4.00}(PO_4)_6(OH)_{3.34} \cdot 12.61H_2O$

Montgomeryite, Tip Top mine:

$(Ca_{3.97}Mn_{0.08})Mg_{1.01}Al_{3.89}(PO_4)_6(OH)_{4.06} \cdot 12.94H_2O$

Hence, it is clear that the material from the Moculta quarry has an average composition with Fe^{+3} greater than Al and with approximately 1 Mg atom per formula unit. It appears that calcioferrite is the ferric iron analog of montgomeryite (*vide supra*). It should be noted, though, that the Fe^{+3}:Al ratio in different crystals of the Moculta material varies from 2.51:1.23 to 1.78:2.43, so both calcioferrite and montgomeryite appear to be present, even in a single spherule! (All Fe is presumed to be Fe^{+3}.)

OPTICAL DATA

Preliminary optical examination of Moculta quarry calcioferrite showed its indices of refraction to be in the range 1.60–1.62, and it was not possible to match these indices with those of any known phosphate mineral. Calcioferrite was not initially suspected since the published data for this mineral (summarized in Palache *et al.,* 1951) indicate it to be uniaxial negative, nearly isotropic, with $n_0 = 1.57$–1.58.

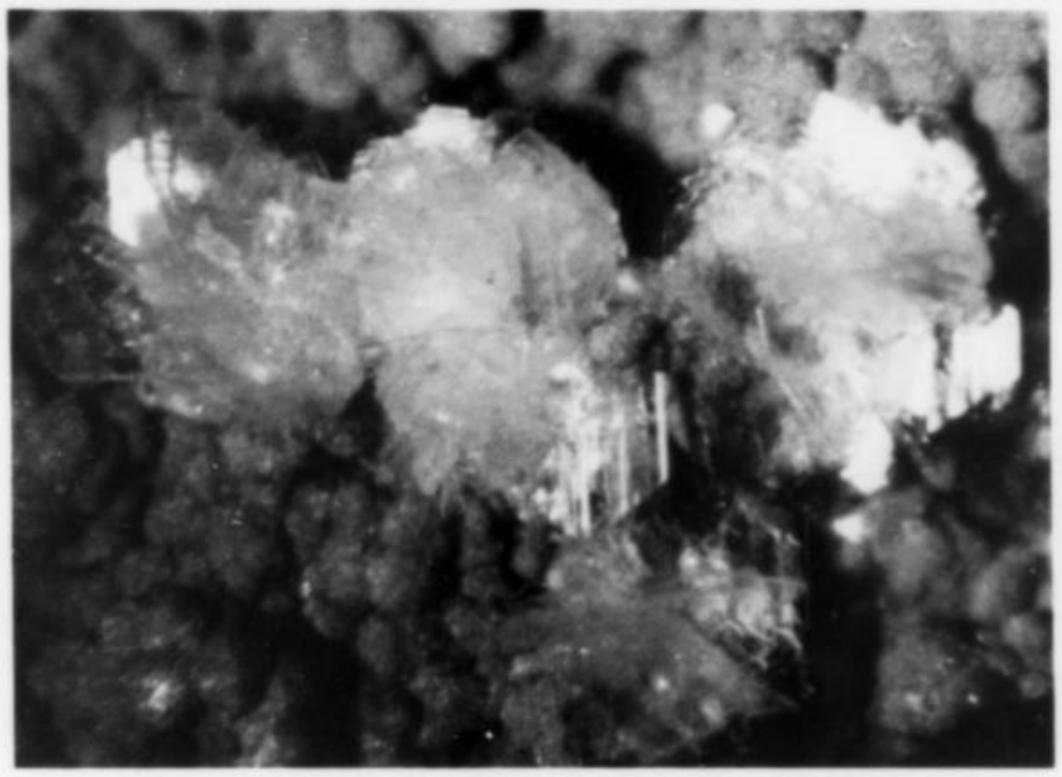

Figure 3. **Clusters of greenish yellow calcioferrite crystals on yellow-brown, botryoidal matrix. Field of view, 1.5 mm.**

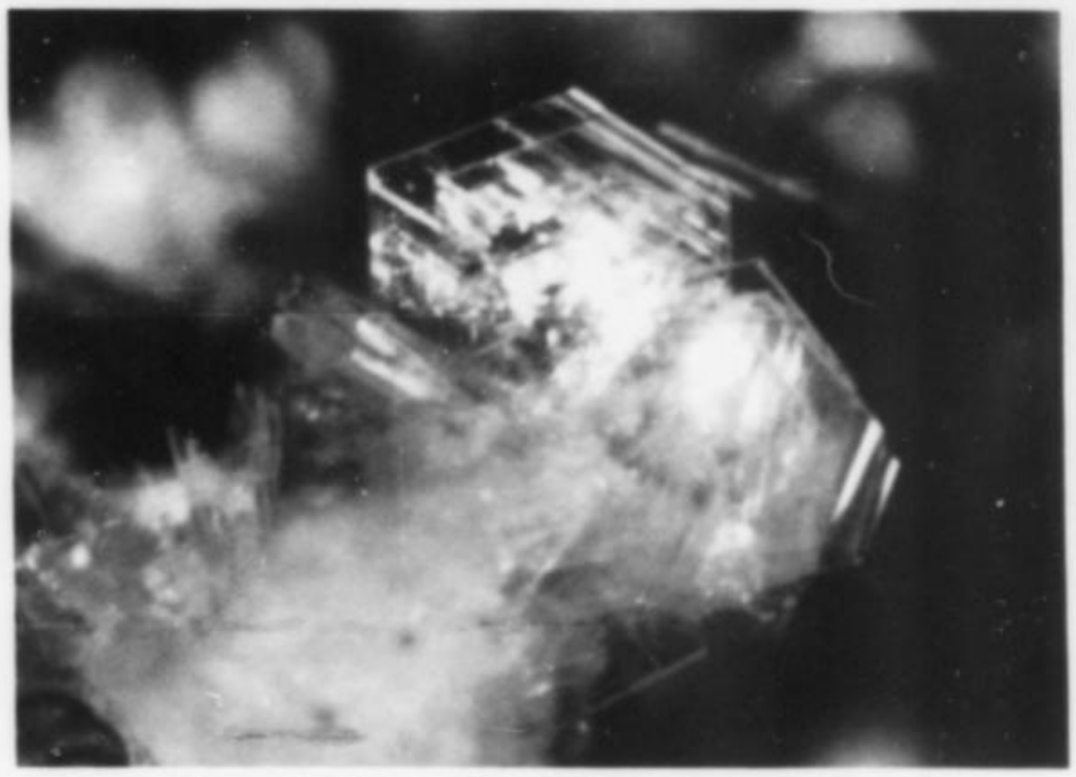

Figure 4. **Bright yellow calcioferrite crystals, the largest is 0.3 mm across.**

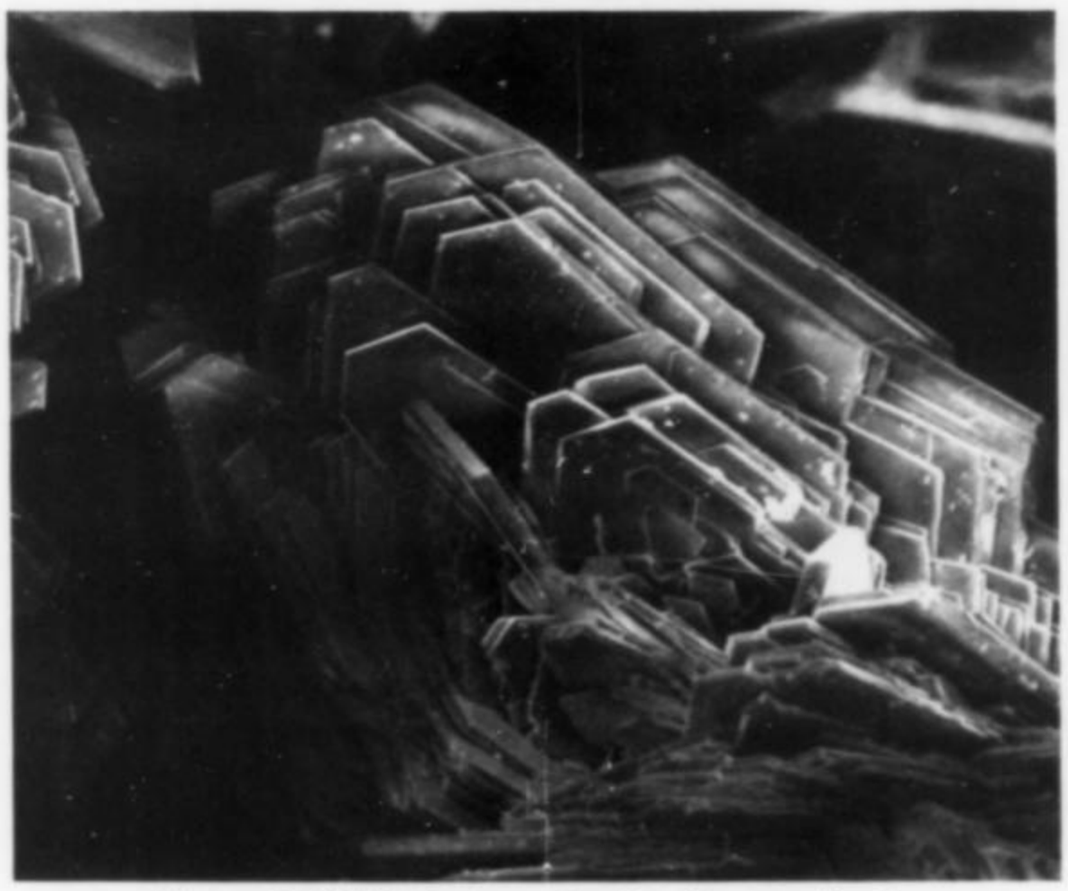

Figure 5. **SEM photograph of a cluster of calcioferrite crystals up to 0.2 mm in size.**

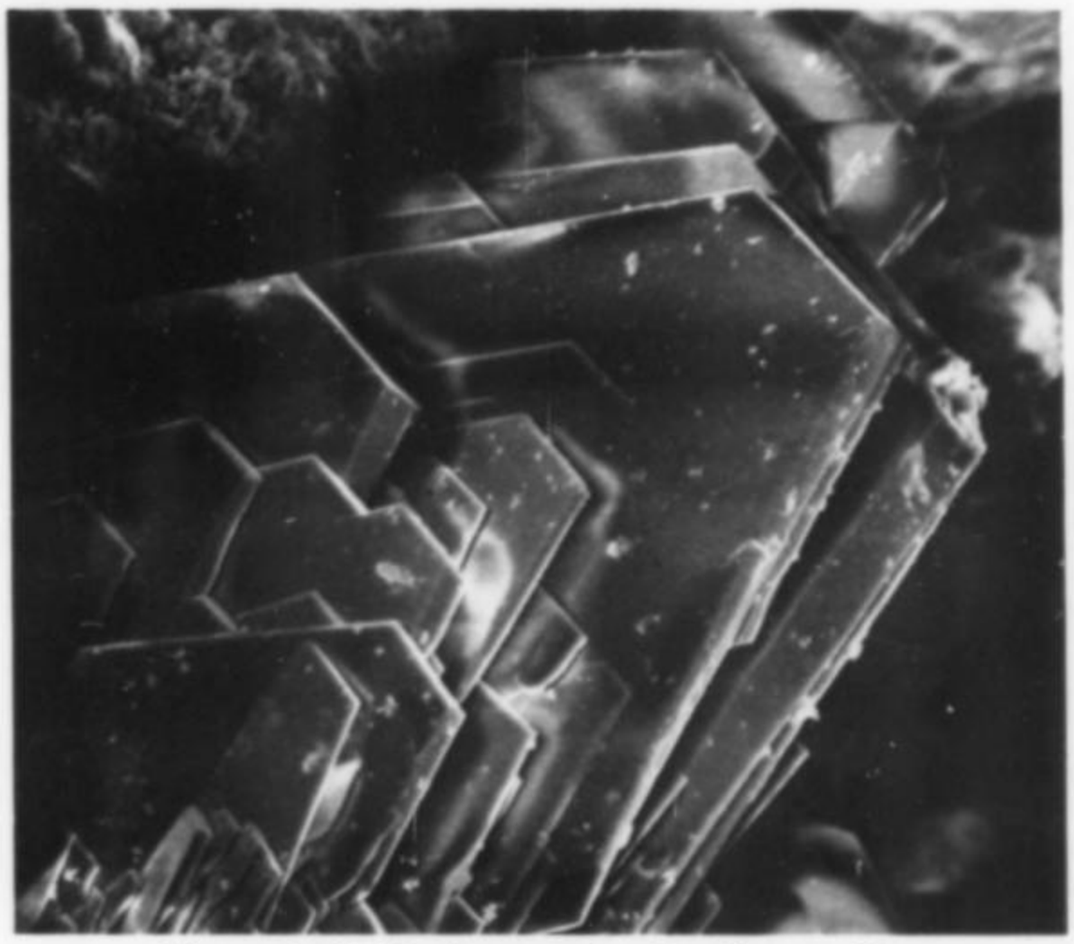

Figure 6. **SEM photograph of pale greenish yellow calcioferrite crystals. Largest crystal, 0.3 mm across.**

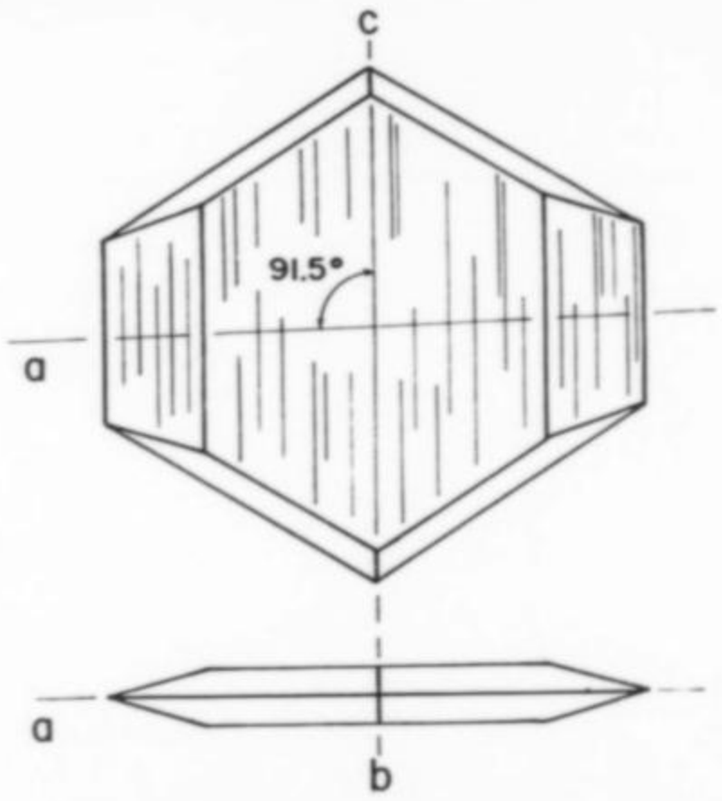

Figure 7. **Sketch of calcioferrite crystal from the Moculta quarry. The direction of the crystallographic axes is inferred from the optical properties and those for montgomeryite.**

Following identification of the Moculta material as calcioferrite on the basis of its X-ray powder pattern and chemical analysis, its optical properties were more carefully examined. It was found that the material is biaxial, with indices of refraction $\alpha = 1.604$, $\beta = 1.610$ and $\gamma = 1.612$ using white light, with $X \wedge c = 61.5°$, and $Z = b$. This is to be compared with the data of Dunn *et al.* (1983) for Tip Top mine montgomeryite. They found $\alpha = 1.572$, $\beta = 1.579$, $\gamma = 1.582$, $X \wedge c = +60°$, $X = b$.

It should be noted that the indices of refraction reported for calcioferrite from the Moculta quarry were among the highest observed for a single crystal. Other crystals gave considerably lower values. This is not surprising since microprobe analyses had indicated solid solution variations between calcioferrite and montgomeryite, the latter having considerably lower indices of refraction.

CONCLUSION

The Moculta quarry, South Australia, appears to be the second world locality for calcioferrite. The X-ray powder data and chemical analysis support the proposition that calcioferrite is the ferric iron analog of montgomeryite, as does the close association of the two species within single spherules at the Moculta quarry.

Calcioferrite at both known localities occurs in low-temperature deposits associated with clay minerals. Moculta material is found in close association with altered pyrite, which may be the source of ferric iron. It is quite possible that chemical analyses of "montgomeryite" from similar environments would reveal additional occurrences of calcioferrite.

ACKNOWLEDGMENTS

The authors are most deeply indebted to Pete J. Dunn of the Smithsonian Institution, without whose aid this paper could not have been written. We also thank Joseph A. Mandarino for his helpful suggestions, and Carol Garland for the SEM photographs.

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Fibrous Rutile
from Franklin, New Jersey

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Newark, New Jersey 07103

The varied mineral assemblages of the Buckwheat dolomite in Franklin, New Jersey, have recently been described in detail by Peters *et al.* (1983). In Figure 18 of their paper, an unidentified mineral referred to as "mountain leather," is shown in association with hemimorphite. "Mountain leather" is usually used to refer to a fabric-like aggregate of flexible mineral fibers with an interlaced growth habit. Fabric-like habit has been noted previously in palygorskite, sepiolite, tremolite-actinolite and chrysotile (Martin-Vivaldi and Robertson, 1971; Zoltai, 1981).

A sample of the Buckwheat "mountain leather" was obtained from Thomas Peters of the Paterson Museum, Paterson, New Jersey. On the basis of its energy-dispersive X-ray spectrum and other data, the fibrous mineral was identified as rutile. The Buckwheat dolomite is noted for the occurrence of hair-like crystals of rutile (Peters *et al.*, 1983), but flexible-fiber bundles of rutile have not been previously reported.

Rutile "mountain leather" is composed of thin, paper-like to stringy masses (Fig. 1) that coat vuggy crystals of dolomite and form thin layers between adjoining dolomite crystals. The masses are of very pale lavender color, and have a silky, sub-metallic

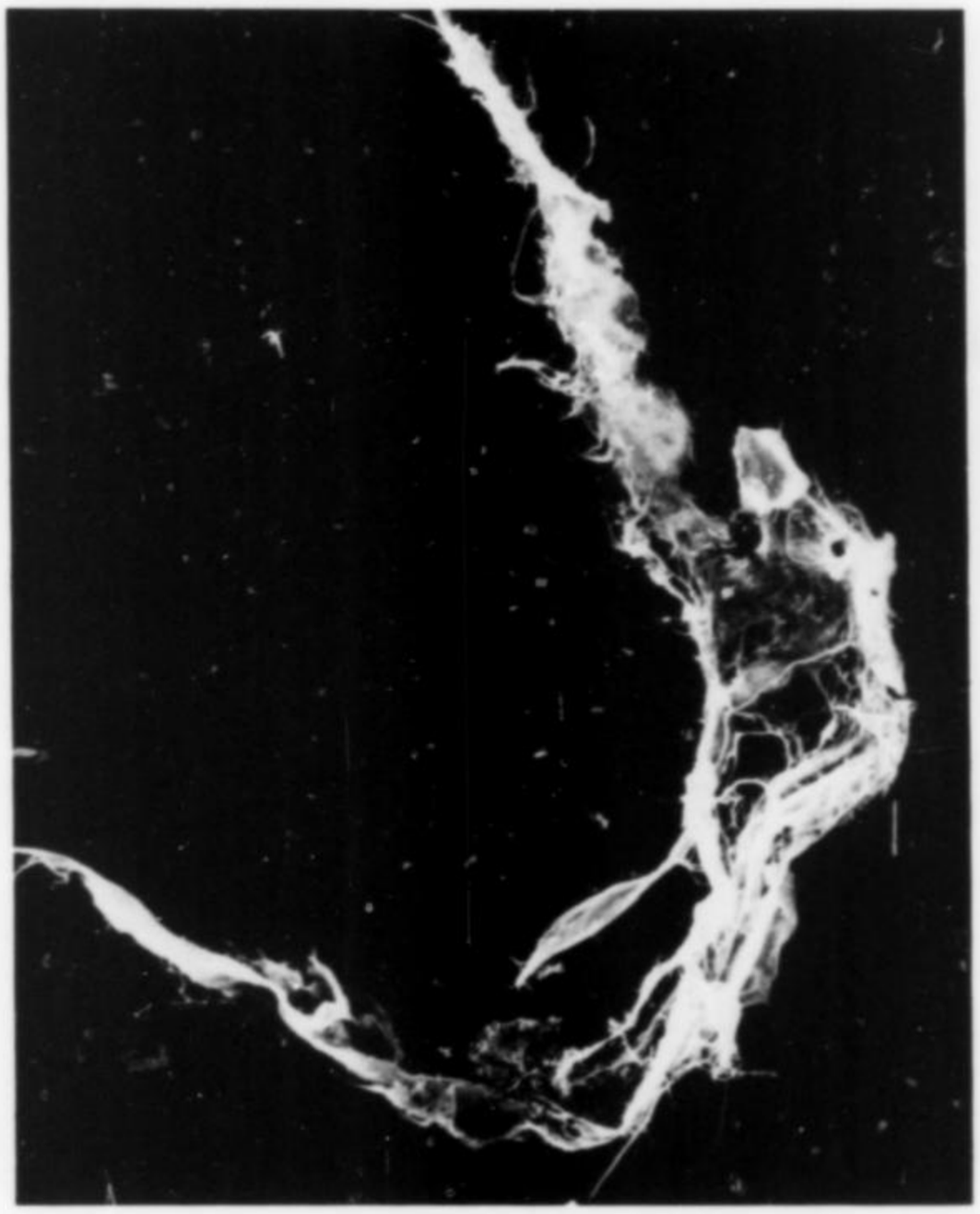

Figure 1. **Scanning electron micrograph of rutile "mountain leather." Maximum dimension of aggregate is about 2.1 mm. White bar to right of aggregate represents 100 micrometers.**

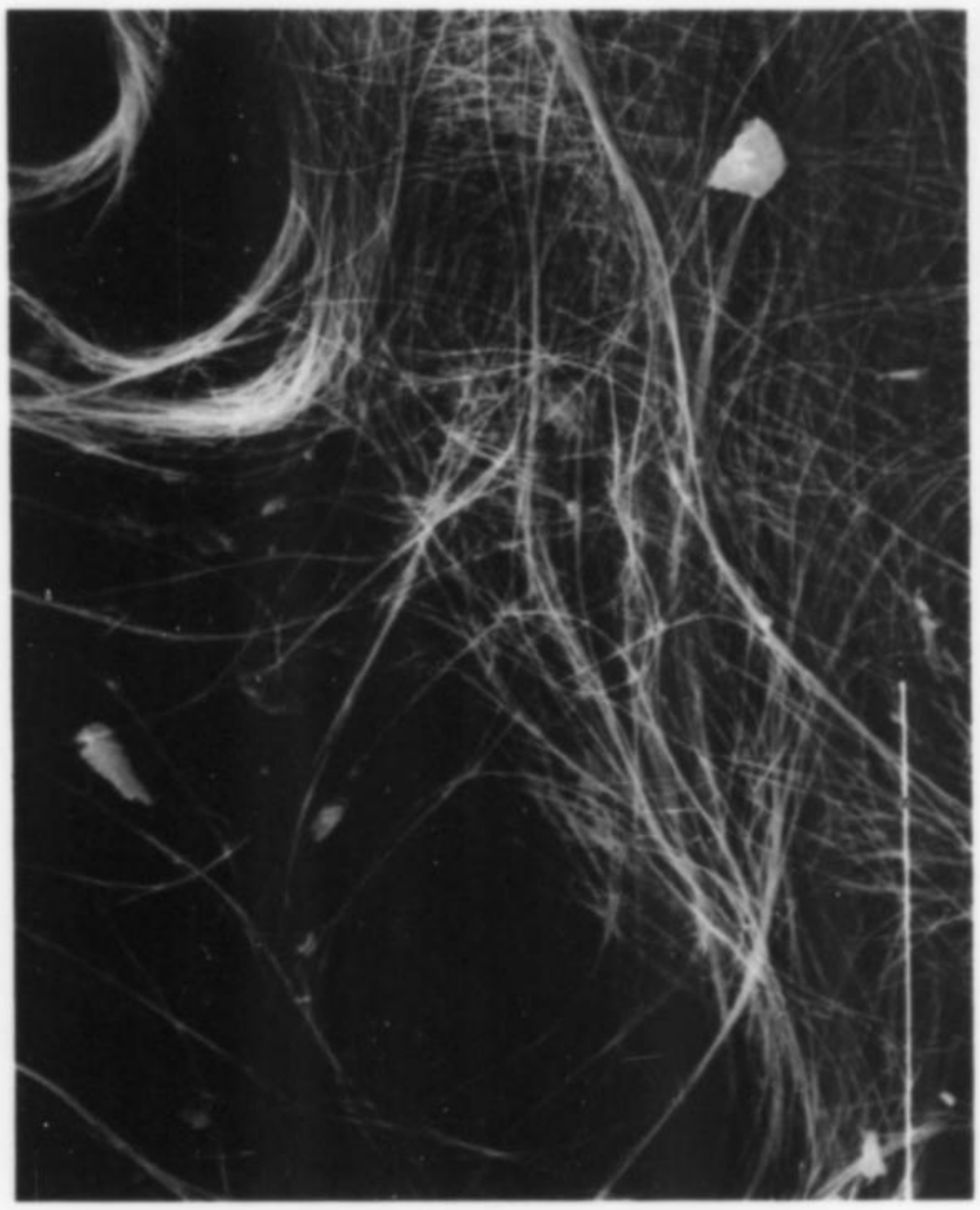

Figure 2. **Scanning electron micrograph showing fibrous habit of rutile "mountain leather." Length of field is about 0.1 mm. Small white bar represents 10 micrometers.**

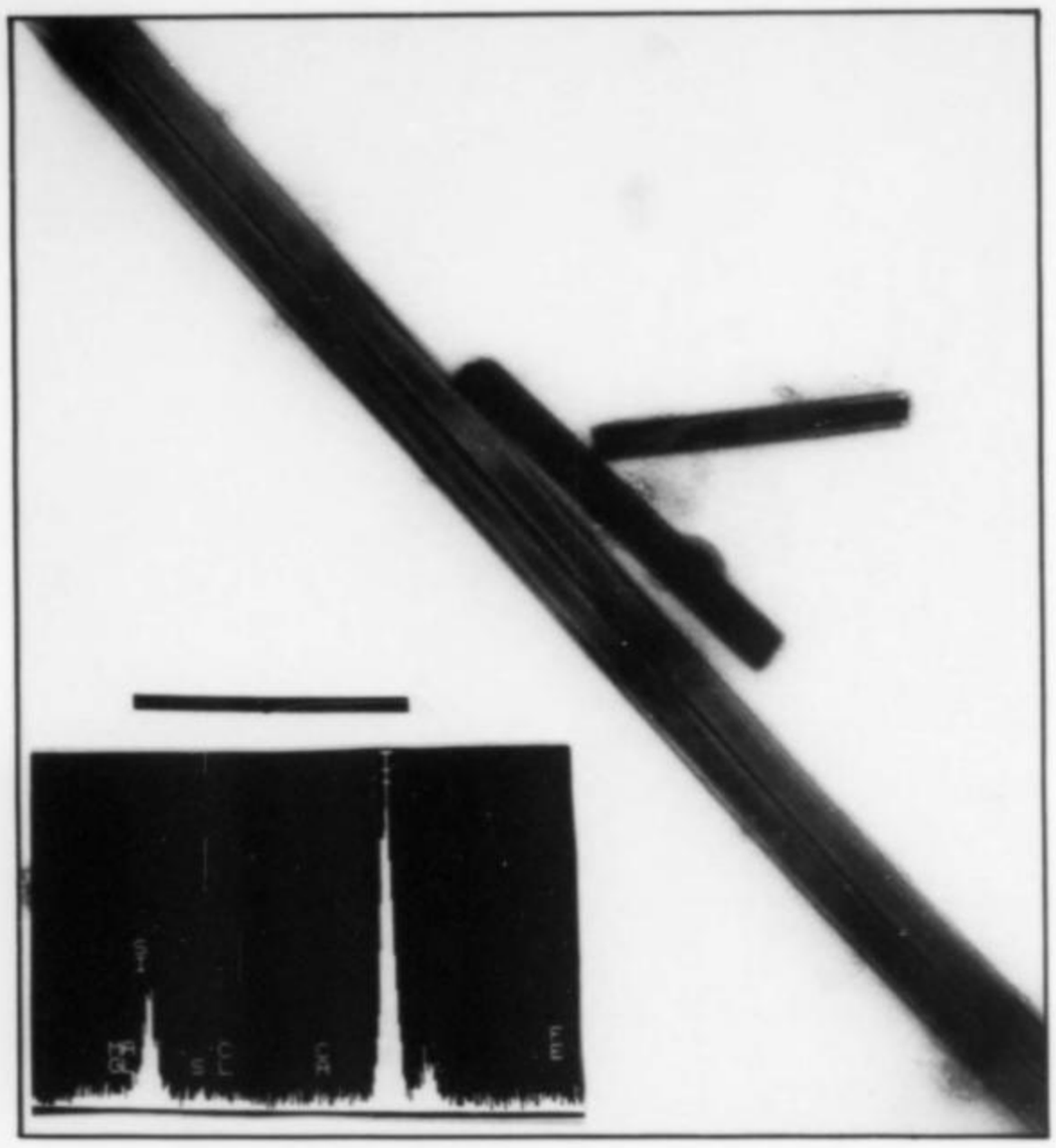

Figure 3. **Transmission electron micrograph of individual rutile fibers (ground sample). Note delicate bend contours and periodic irregularities (possible dislocations) along fiber lengths. Energy dispersive spectrum is shown on lower left, along with scale bar representing 0.5 micrometers.**

luster. In transmitted polarized light, individual fiber-bundles have parallel extinction, and are pleochroic from light yellowish brown to dark brown. Masses of the fiber are dark brown and nearly opaque in transmitted light. Fibrous aggregates are insoluble in cold, concentrated hydrofluoric acid, consistent with their identification as rutile (Raman and Jackson, 1965).

Scanning electron microscope (SEM) examinations reveal a delicate, fibrous growth habit consisting of bundles of long, flexible fibers (Fig. 2). Energy dispersive X-ray (EDX) data gathered under the SEM indicate that the fibers are composed mostly of titanium dioxide, with a small amount of iron. Silicon, aluminum, calcium and magnesium were also detected on EDX spectra, but are thought to be associated with scattered grains of other minerals such as calcite, dolomite and talc.

Transmission electron microscope examinations show that fibrous aggregates of rutile are composed of ultrafine crystals (Fig. 3). Individual crystals have relatively uniform widths, typically ranging from 0.07 to 0.10 micrometers. Electron diffraction and energy dispersive X-ray spectroscopy were used to confirm the identification of individual rutile crystals under the transmission electron microscope. Electron diffraction indicated that crystals usually lie on (110). A c/a ratio of 0.64 to 0.65 was calculated from (110) diffraction nets, in excellent agreement with the ratio (0.6442) for rutile given by Palache *et al.* (1944).

Flexibility and strength, characteristic of the rutile described here, are developed in fibers as a function of decreasing diameter (Zoltai, 1981). These properties, in turn, give rise to other characteristics of fibrous minerals, such as fabric-like habit. The differences in habit between rutile "mountain leather" and acicular rutile may thus be explained by differences in crystal diameter.

The formation of fibers and other ultrafine crystals is favored by rapidly changing conditions which can lead to rapid nucleation and crystal growth (Hyndman, 1972; Ross, 1978; Zoltai, 1981). Crystalline disorder, again favored by disequilibrium conditions, may also favor a fibrous growth habit by limiting width-wise crystal growth (Ross, 1978).

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the Gardiner Complex
a new locality in Greenland

The Gardiner complex is a remarkable locality. In a short span of time totalling just two weeks in 1975 and 1982, expeditions there recovered outstanding suites of perovskite, magnetite, andradite and other species. The perovskite specimens in particular rank among the world's finest.

INTRODUCTION

The Gardiner complex is an ultramafic alkaline intrusion located on a nunatak beyond the head of Kangerdlugssuaq Fiord in East Greenland. Geologically, the Kangerdlugssuaq region is a part of the East Greenland Tertiary province and is a key area in the understanding of the early stages of continental break-up in the North Atlantic (Brooks and Nielsen, 1982).

The present exposure of the intrusion is at a high level with the contacts generally dipping away from the center. Relief ranges from Anorerssuaq peak at 2040 m elevation to Gardiner Lake at 700 m. Almost half of the intrusion is more or less covered with crevassed glaciers but the rest is well exposed.

HISTORY

The exploration history of the Gardiner complex is a short one. The locality was briefly mentioned by Wager (1937, 1947) in his reports on the Kangerdlugssuaq expedition, 1935–36. During their Ice Cap journey two members of the expedition, Deer and Fountaine, made a short detour to Gardiner where they collected fine crystals of magnetite on tremolite. They considered Gardiner as being a part of the Archaean basement.

The Gardiner complex rested in peace until 1971 when the intrusion was rediscovered during a reconnaissance flight, and the same year a team from Nordisk Mineselskab A/S was assigned two weeks field work at Gardiner and gave a preliminary description of the intrusion (Frisch and Keusen, 1975, 1977). Later, teams of the Brooks Kangerdlugssuaq expeditions 1975 and 1982 were put down at Gardiner. One of us (O.J.) was present on both occasions, and it is on material collected during these visits that the following description of the minerals is based.

Gardiner complex is, mildly speaking, an extremely remote place. Only every 30 years or so does the ice break up in the inner parts of Kangerdlugssuaq Fiord and, even if one could reach the Kangerdlugssuaq glacier front by boat, further travel to Gardiner would be most difficult because highly crevassed glaciers must be crossed. So the only access to the complex is by helicopter – at least in summertime. Due to the remoteness of the Gardiner complex (more than three hours flying time from Kulusuk near Angmassalik to Gardiner), helicopter transportation must be carefully planned, with fuel depots put down the year before. In 1982 a field work period of four weeks at Gardiner was planned but, due to various circumstances, bad weather, radio black-out, etc., the period ended after six days, two of which were spent inside the tents because of stormy weather.

Before we enter the geology and mineralogy sections a few words should be said about working conditions when staying at Gardiner. Wager (1937) already mentioned the almost constant gale winds

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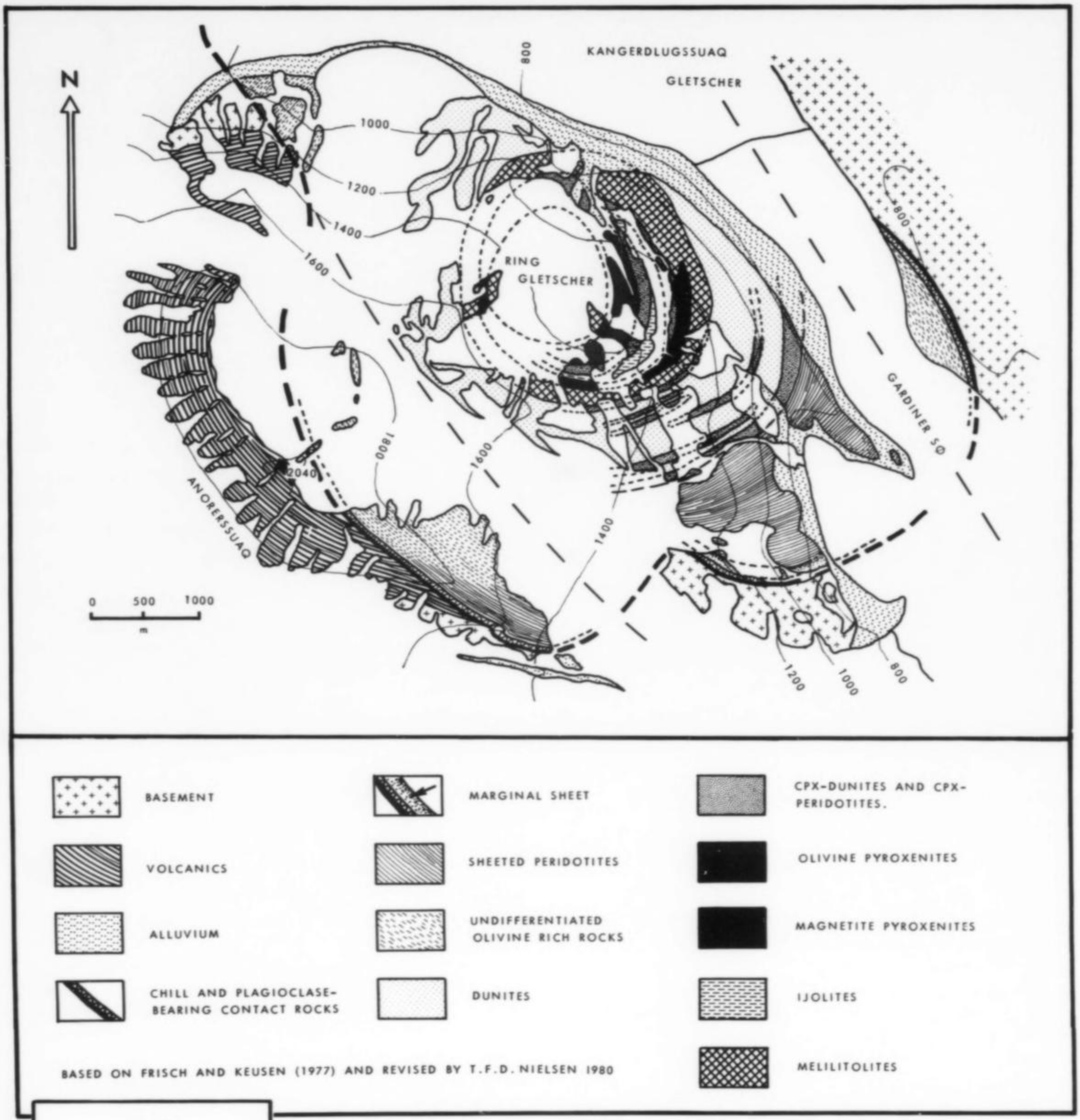

Figure 1. **Geological map of the Gardiner complex.**

from the Ice Cap towards the Kangerdlugssuaq Fiord. The team from Nordisk Mineselskab A/S had to call in new tents and move by helicopter to a more sheltered camping place, and the people visiting Gardiner in 1975 and 1982 also had problems with their tents although these tents were specially designed for arctic conditions. The wind does make it troublesome to live at Gardiner, and it also has a serious effect on mineral collecting. Phlogopite is an abundant mineral in the complex and, due to the strong winds, this mineral (and many others, too) are also very abundant in the lower part of the atmosphere.

GEOLOGY

The Gardiner complex is unique in the North Atlantic province. It is a zoned ring-shaped intrusion approximately 6 km in diameter. The dominant rocks are dunite and pyroxenite with ring dikes of melilite rocks and various dikes and veins of nepheline syenite and

Figure 2. **A relatively sheltered camping place at Gardiner Lake. It is not possible to depict wind with a speed of 20–25 m/sec, but notice the apse of the tent and the drift ice on the lake packed to the leeward side.**

carbonatite. The complex is emplaced at the basement/plateau basalt boundary and represents an eroded core of a nephelinitic volcano (Nielsen, 1981). Structurally, the intrusion is related to a rift-like feature along the Kangerdlugssuaq Fiord, and the intrusion itself is cut by two fiord-parallel faults. The age of the complex has been determined by fission track dating of apatite and titanite to be 50.3 ± 1.4 m.y. (Gleadow and Brooks, 1979).

The geology of the Gardiner complex has been described by Frisch and Keusen (1975, 1977) and Nielsen (1980, 1981). The evolution of the complex can be divided into four phases: (1) an older ultramafic cumulate series, (2) a shonkinite to nepheline syenite suite of minor cone sheets and dikes, (3) massive ijolite and melilitolite dikes and sheets, related melteigite, syenite and carbonatite dikes and sheets, and (4) a volumetrically less important terminal suite of alkali pyroxenite, nepheline syenite and urtite dikes and sheets.

The ultramafic cumulate series constitutes the major part of the complex and forms a succession of more or less concentric zones that are increasingly younger towards the center. The cumulates are dunites, peridotites and pyroxenites, commonly with a banded structure. The banded peridotites are most common in the outer parts while the dunites are dominant in the inner parts of the intrusion. Some of the ultramafic rocks, in particular the dunites, are often affected by alkali-metasomatism, and this is especially pronounced in the vicinity of the melilitolites. At the contact to the surrounding gneisses and alkaline basalts, a 1 to 10-meter-wide zone of chilled plagioclase-bearing alkaline rocks is developed. The contact is vertical in the area of Anorerssuaq; elsewhere it dips 35–50° away from the center.

A sequence of dikes and minor cone sheets separates in time the ultramafic cumulates from the younger ijolite, melilitolite and related rocks. These dikes and sheets are nearly all concentric or radial, and some cut the country rocks. The compositions range from melanocratic syenite (shonkinite) to leucocratic syenite.

The prominent feature of the Gardiner complex is the formation of melilitolite ring dikes and related ijolite, melteigite, syenite and carbonatite dikes and sheets. Melilitolites are ultramafic rocks with 70–80% melilite and minor amounts of clinopyroxene, perovskite, magnetite and apatite. Uncompahgrite (type locality Iron Hill, Colorado) is a melilitolite with clinopyroxene and only small amounts of apatite, while rocks with larger amounts of apatite and subordinate clinopyroxene are defined as afrikandite (type locality Afrikanda, Kola Peninsula). The melilitolites appear as tough, massive rocks generally with a yellow-brown color due to weathering.

The melilitolite rocks are exposed in two bodies in the Gardiner complex, a central body and an outer ring dike. The central body has a diameter of 1100–1300 m and is mostly covered by Ringgletscher, which means that the exact nature of the interior part is unknown. The outer ring dike is 100–300 m wide and nearly concentric. It is mainly exposed in the eastern parts of the intrusion from 900 m elevation to the north to 1600 m level to the south. The lower parts of the ring dike are zoned with afrikandite in the interior and uncompahgrite at the contacts. Locally, the melilitolites

are enriched in magnetite, perovskite, apatite, phlogopite and melanite (a titaniferous variety of andradite) forming clusters or layers 1–10 cm wide. Massive concentrations of perovskite and/or magnetite occur, especially in the inner contact zone. At the upper level of the ring dike (elevation 1400 m) – where the melilitolites are roofed by later alkali pyroxenite, ijolite ring dike and dunite of the older sequence – the afrikandite transforms into coarse-grained turjaite (melilitolite with nepheline and calcite) and carbonate-rich veins. These veins consist of natrolite, calcite and melanite. The roof zone above the melilitolites is characterized by pegmatites of turjaitic or melteigitic compositions and by coarse-grained apatite-phlogopite rocks with veins or patches of a sodalite syenite assemblage. Another group of veins and pegmatites related to the upper part of the ring dike includes carbonatites (søvite dikes) and magnetite-phlogopite-diopside-calcite pegmatites.

In the vicinity of the melilitolites, in particular in the areas between the two melilitolite bodies, the older rocks have been strongly altered by alkali-metasomatism. Phlogopite is the most abundant mineral in the alteration zones; most pronounced is the formation of a 6–8 m wide phlogopite zone (glimmerite) running concentrically close to the inner contact of the melilitolite ring dike. The alteration zones are characterized by large crystals of phlogopite, diopside, magnetite, etc.

The closing intrusive event in the Gardiner complex is considered to be the introduction of dikes and sheets of alkali pyroxenite, nepheline syenite, albitite and urtite.

MINERALOGY

Table 1 lists more than 60 minerals so far known from the Gardiner complex. A description of all of them is beyond the scope of this article, but several of the more important species are described below.

Perovskite $CaTiO_3$

Perovskite is undoubtedly the most remarkable mineral in the complex. It occurs in the melilitolites and in the alkali-metasomatically altered rocks in association with one or more of the minerals melilite, apatite, magnetite, diopside and phlogopite. Perovskite is present in various amounts, sometimes evenly distributed, sometimes in a layered arrangement with other minerals and sometimes as clusters. Locally, meter-size massive concentrations of perovskite forming up to 50% or more of the rock can be found.

At least two generations of perovskite have been observed, but most of the perovskite is early-formed as euhedral to subhedral grains. The best crystallized perovskite is found in an easily crumbled rock composed solely of apatite and perovskite in up to 1-meter bodies.

The crystal habit of Gardiner perovskite is somewhat unusual. The most frequent habit is a combination of {110} and {011} (or, to phrase it in a cubic setting, the octahedron only). In rare cases small faces corresponding to the cube, {101} and {010}, are found. The size of the crystals is extraordinary, with dimensions up to 8 cm on an edge; these, as far as we know, are the largest perovskite crystals ever recorded.

Some of the biggest crystals have a rather dull luster, while others, mainly crystals coming from pockets in a border zone between the ring dike and the inner dunite, have brilliant faces with metallic to adamantine luster. Crystals originating from the apatite-perovskite rock are generally smaller (5–20 mm) and have a slightly pitchy or greasy luster. The color is black, sometimes with a grayish or brownish hue; in thin section it is reddish and occasionally zoned. Striations due to polysynthetic twinning are common.

The chemistry of Gardiner perovskite varies from essentially pure $CaTiO_3$ to compositions with substitution of rare earths (chiefly cerium for calcium, and niobium for titanium; Frisch and Keusen, 1977). The secondary perovskite is almost pure, while the primary shows substitutions of the kind mentioned, possibly in a systematic manner in the ring dike.

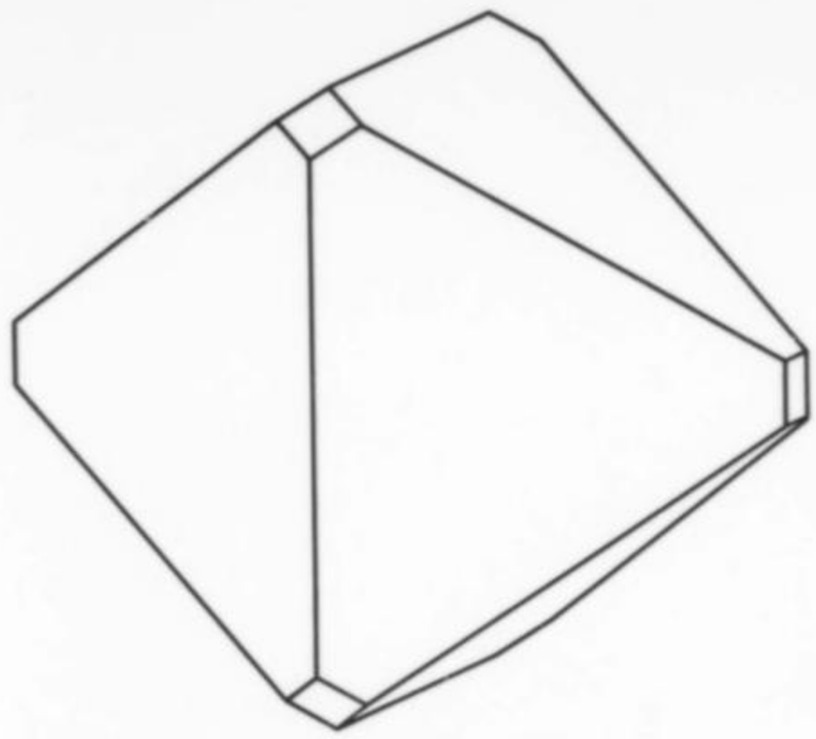

Figure 3. **Drawing of a perovskite crystal showing the forms {110}, {011}, {101} and {010} in the monoclinic setting.**

The occurrence of perovskite at the Gardiner complex is exceptional, firstly because of the unique size of the crystals, secondly because of the abundance of the mineral in the intrusion, and thirdly because of the predominantly octahedral habit.

Magnetite $Fe^{+2}Fe_2^{+3}O_4$

Magnetite is widespread in the intrusion as an accessory mineral in the dunite and pyroxenite of the older sequence as well as in the

Figure 4. **"Pavement" of magnetite lumps. Hammer shaft is 35 cm long.**

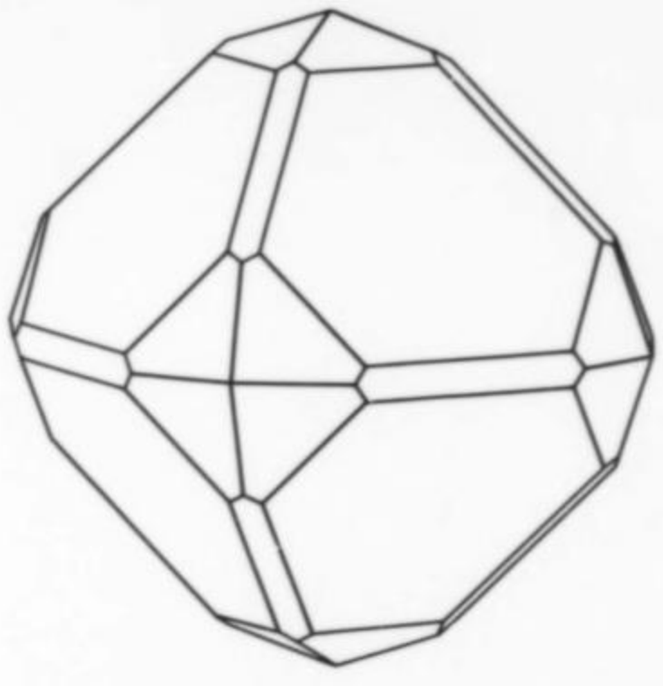

Figure 5. **Drawing of a magnetite crystal with the forms {110}, {111} and {311}.**

abrasion. Some of the smaller loose crystals or clusters of crystals from the phlogopite deposits do have sharp edges and shiny faces. The crystal habit is {111}, sometimes in combination with {110} and {311}.

Specimens of well-crystallized magnetite on tremolite and diopside have been found in small veins or lenses in dunite and pyroxenite, also outside the zone with the altered rocks. These crystals rarely exceed 5 cm on an edge.

Hydroxylapatite $Ca_5(PO_4)_3(OH)$

Hydroxylapatite is found as an accessory mineral in the melilitolites and as a major constituent in parts of the altered rocks, where it occurs as interstitial masses in the phlogopitic lenses and zones, and as matrix for crystals of perovskite. Hydroxylapatite is most frequently found in solid masses, but also felted masses and aggregates of columnar crystals are seen. Impressions of crystals more than 30 cm in length and 15–20 cm thick have been found.

Well-formed crystals of hydroxylapatite are found in veins with natrolite and sometimes melanite. These crystals, 1–5 cm long, are transparent and greenish to almost colorless. Fractures are com-

Figure 6. **Magnetite crystals. Field: 36 x 42 mm.**

melilitolites. Massive concentrations of magnetite occur locally in the latter rocks as up to 2-meter-thick layers.

Most impressive, however, is the magnetite found in various parts of the metasomatically altered rocks, where coarse-grained phlogopite and magnetite form long zones like the previously mentioned glimmerite, and numerous spots 1–10 m in diameter. These deposits are easily weathered, so the surface consists of coarse-grained gravel more or less paved with lumps of magnetite. These lumps can measure up to 20 cm and weight more than 5 kg. Most of the lumps have none or only a few crystal faces, but some are definitely octahedrons. Generally, the loose crystals have rounded edges and faces with a corroded appearance, but this is not due to

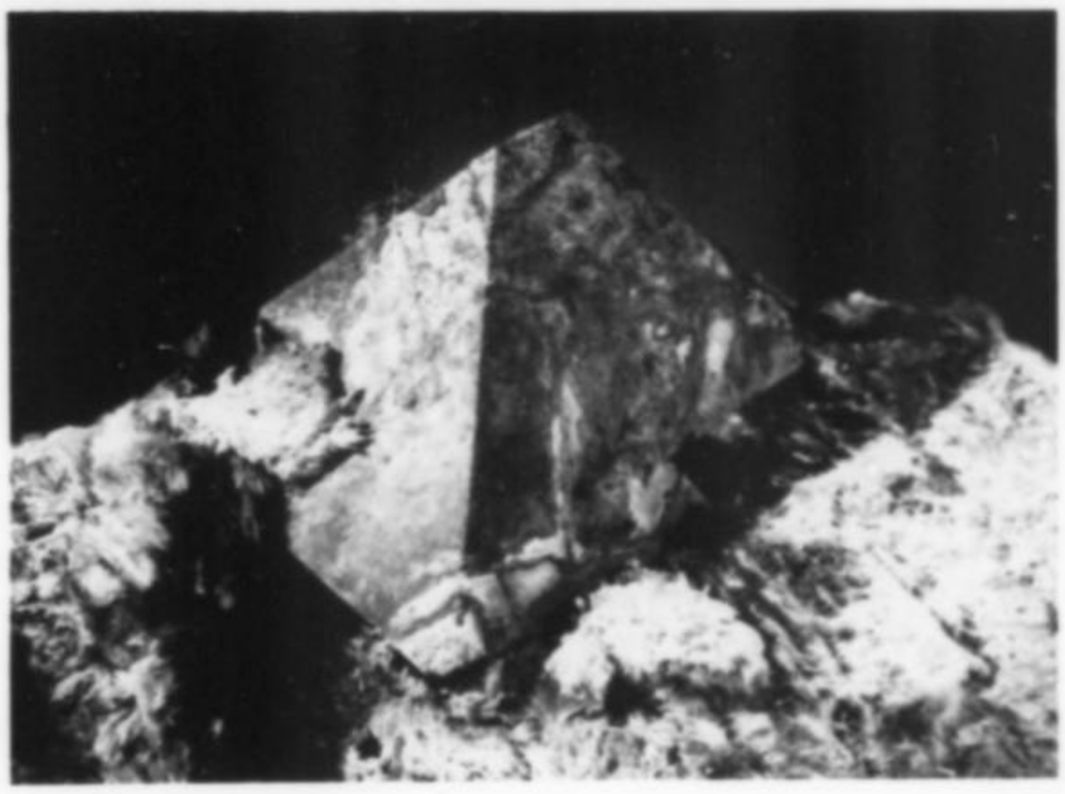

Figure 7. **Magnetite octahedron on tremolite. Field: 90 x 120 mm.**

Figure 8. **Perovskite crystals in hydroxylapatite. Field: 21 x 28 mm.**

Figure 9. **Impression of an apatite crystal, about 15 x 30 cm.**

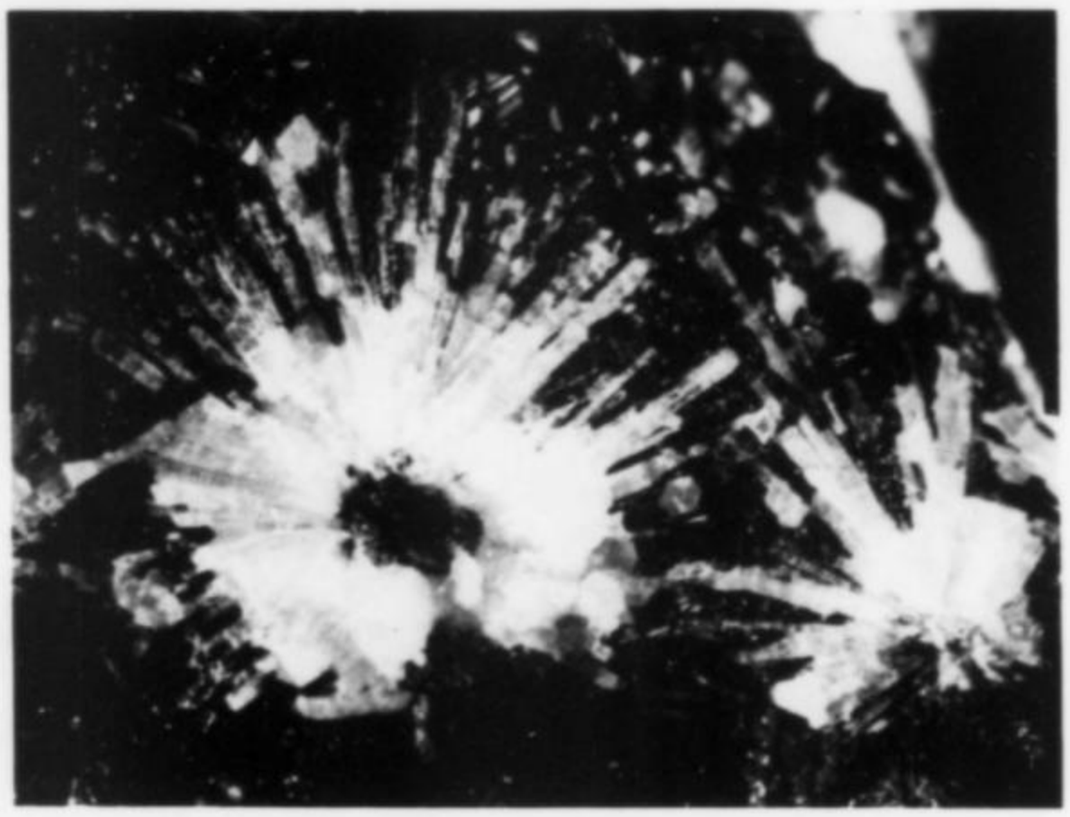

Figure 10. **Radial aggregates of apatite in melanite. Field: 20 x 27 mm.**

mon. The crystal habit is generally simple with basal pinacoid, prism and occasionally bipyramid of the same order. A few specimens have been collected where apatite is seen as small radial aggregates in a melanite matrix.

Andradite (var. melanite) $Ca_3(Fe^{+3},Ti)_2(SiO_4)_3$

Melanite, a titaniferous variety of andradite, occurs sporadically in the melilitolites, especially in areas east of the Ringgletscher. Melanite is developed as large aggregates, commonly without crystal faces but rarely with faces of the form {110} modified by {211}. The size of the crystals is usually a few centimeters but in one case a crystal fragment shows a dimension of 12 cm across.

Another type of occurrence is melanite in natrolite veins associated with calcite, phlogopite and sometimes diopside. Specimens of this type are very beautiful, with black shiny melanite crystals in a white natrolite matrix, the crystals being up to 2 cm across and showing combinations of {110} and {211}.

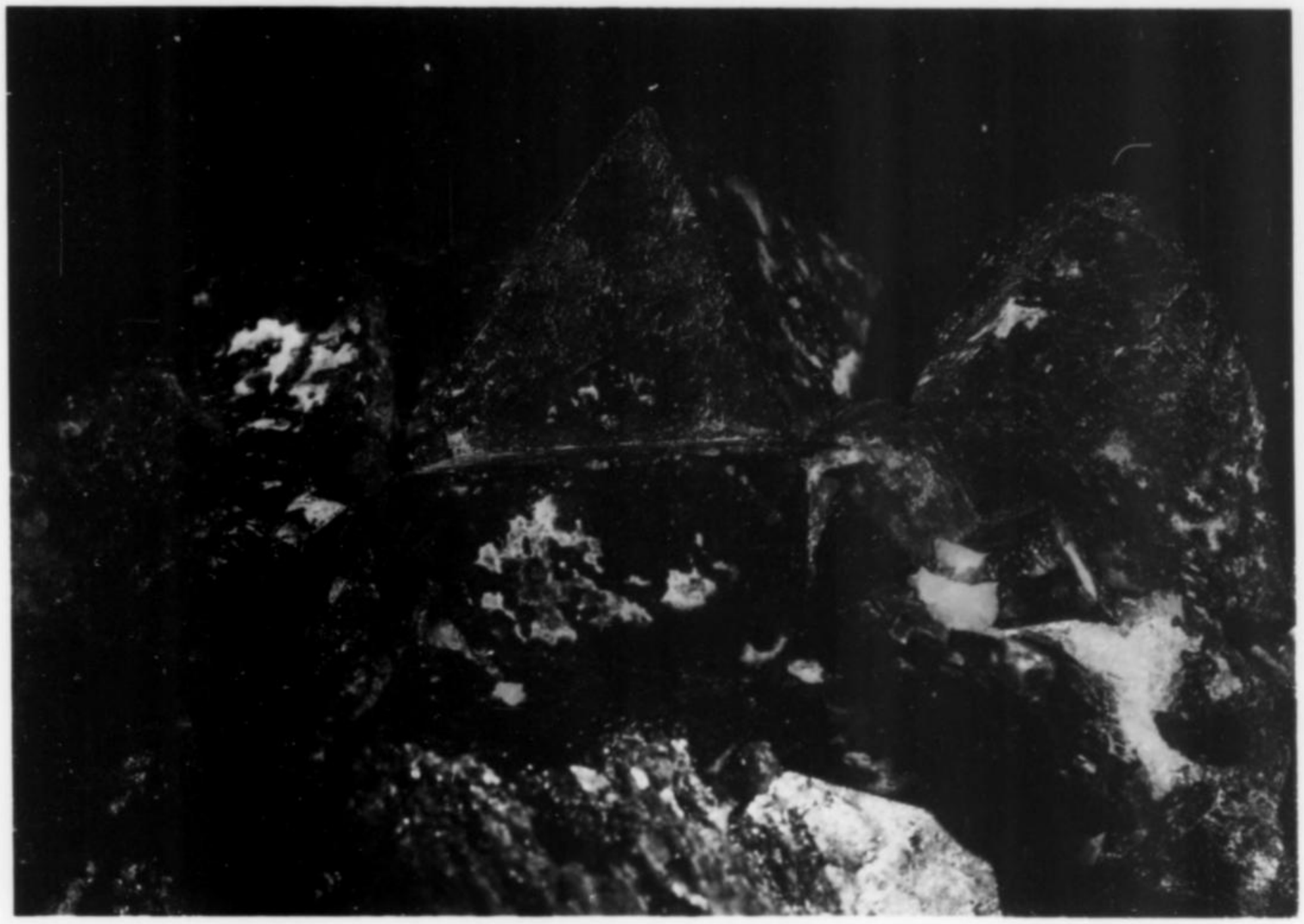

Figure 11. **Perovskite. Field: 54 x 72 mm.**

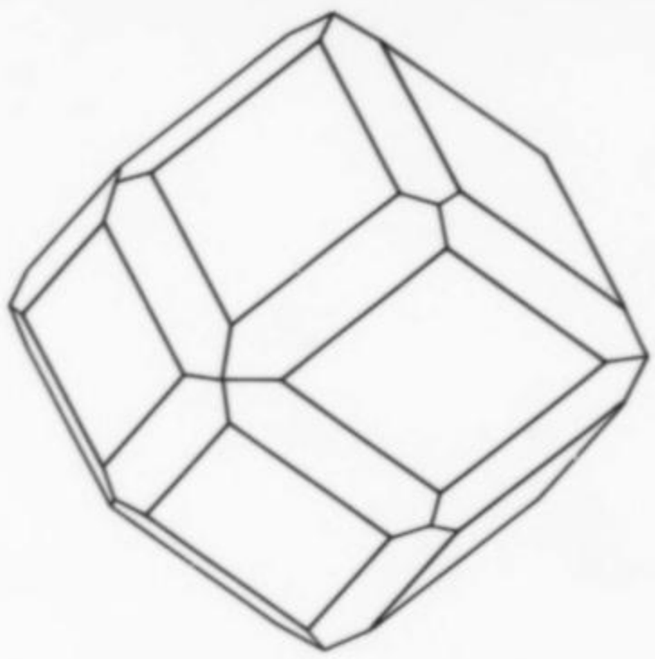

Figure 12. **Drawing of a crystal of andradite (var. melanite) with the forms {110} and {211}.**

Figure 13. **Melanite crystals in natrolite. Field: 54 x 72 mm.**

Figure 14. **Melanite crystal. Field: 16 x 22 mm.**

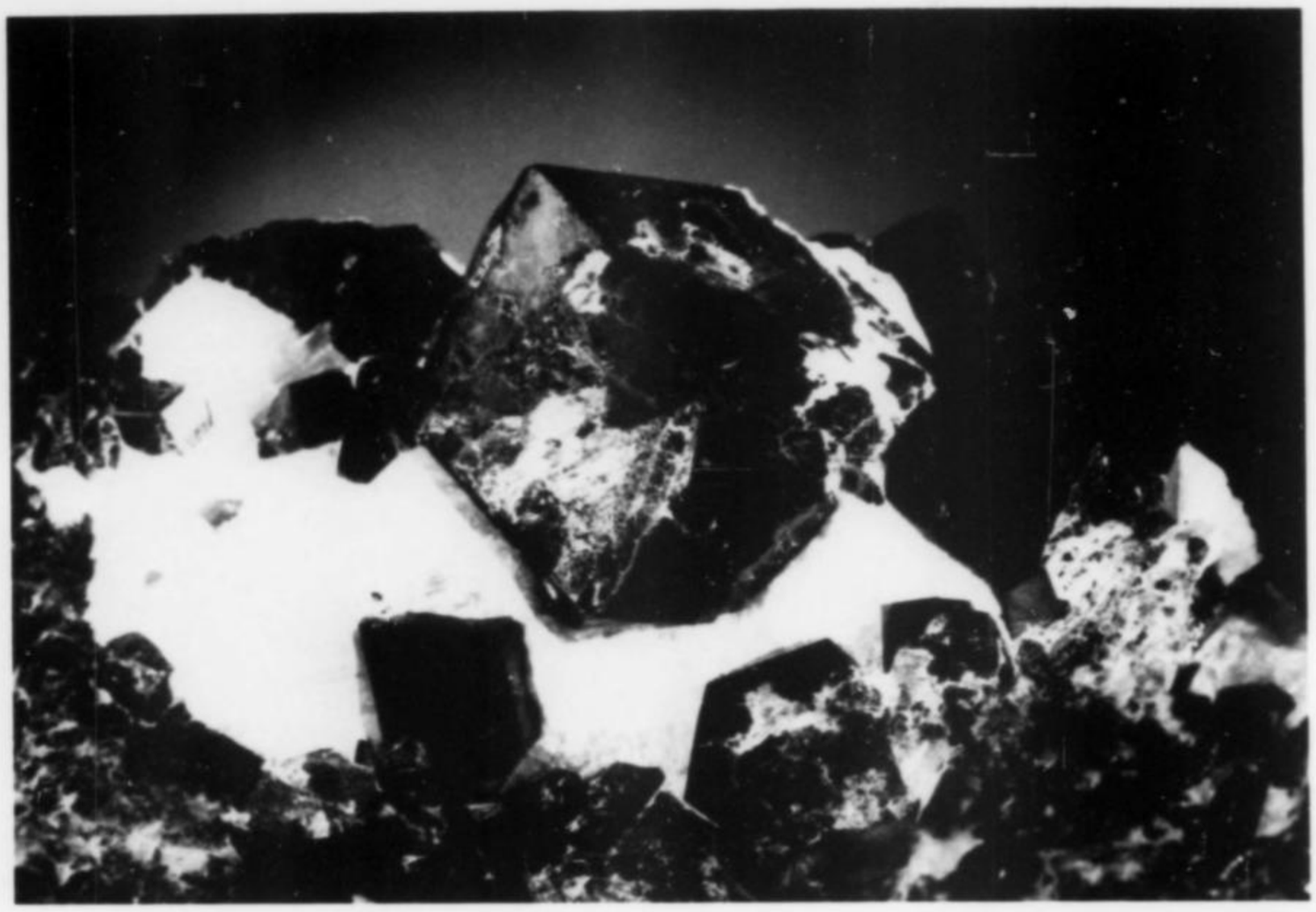

Figure 15. **Crystals of melanite with natrolite. Field: 52 x 72 mm.**

Clinohumite (titaniferous) $(Mg,Fe^{+2},Ti)_9(SiO_4)_4(F,OH)_2$

Titaniferous clinohumite has been reported from Gardiner by Nielsen and Johnsen (1978), occurring in late magmatic veins intruding dunite. The mineral forms reddish brown aggregates up to 10 cm in size in the central parts of these veins. The occurrence is considered to be the first recording of titaniferous clinohumite as a primary phase in late magmatic veins.

Titanite $CaTiSiO_5$

Titanite is probably the one mineral from the Gardiner complex that shows the greatest variation in habit and color. In the majority of specimens it forms aggregates, commonly fan-shaped, or complete rosettes in a matrix of acicular natrolite and stubby amphibole prisms with minor apatite and melanite. The individual crystals of the aggregates are generally 2–4 mm wide and may attain lengths of almost 8 cm. The yellow or yellowish-brown crystals are largely translucent but occasionally transparent. A unique specimen with an isolated, completely transparent, gem-quality single crystal is shown here. In another type of specimen, titanite also forms fan-shaped aggregates, but these aggregates are coarser with crystals up to 13 cm in length. These crystals are reddish brown and opaque; the only accompanying mineral is amphibole. In a third type of specimen, titanite forms complete rosettes of acicular reddish brown crystals, the rosettes attaining sizes of 3–4 cm.

The first two types occur in pockets and as fracture fillings in the melilitolites and in the adjacent ultramafic rocks. The third type of titanite occurs in syenite veins in association with typical nepheline syenite pegmatic minerals.

Lamprophyllite $Na_2(Sr,Ba)_2Ti_3(SiO_4)_4(OH,F)_2$
Barytolamprophyllite $(Na,K)_2(Ba,Ca,Sr)_2(Ti,Fe)_3(SiO_4)_4(O,OH)_2$

These two minerals are found in minor amounts in different parageneses, such as: (1) in melteigite lenses in the contact zone east of Gardiner Lake, (2) in syenite dikes, for instance in association with red eudialyte, and (3) in a number of pockets and veinlets with natrolite and minor pectolite.

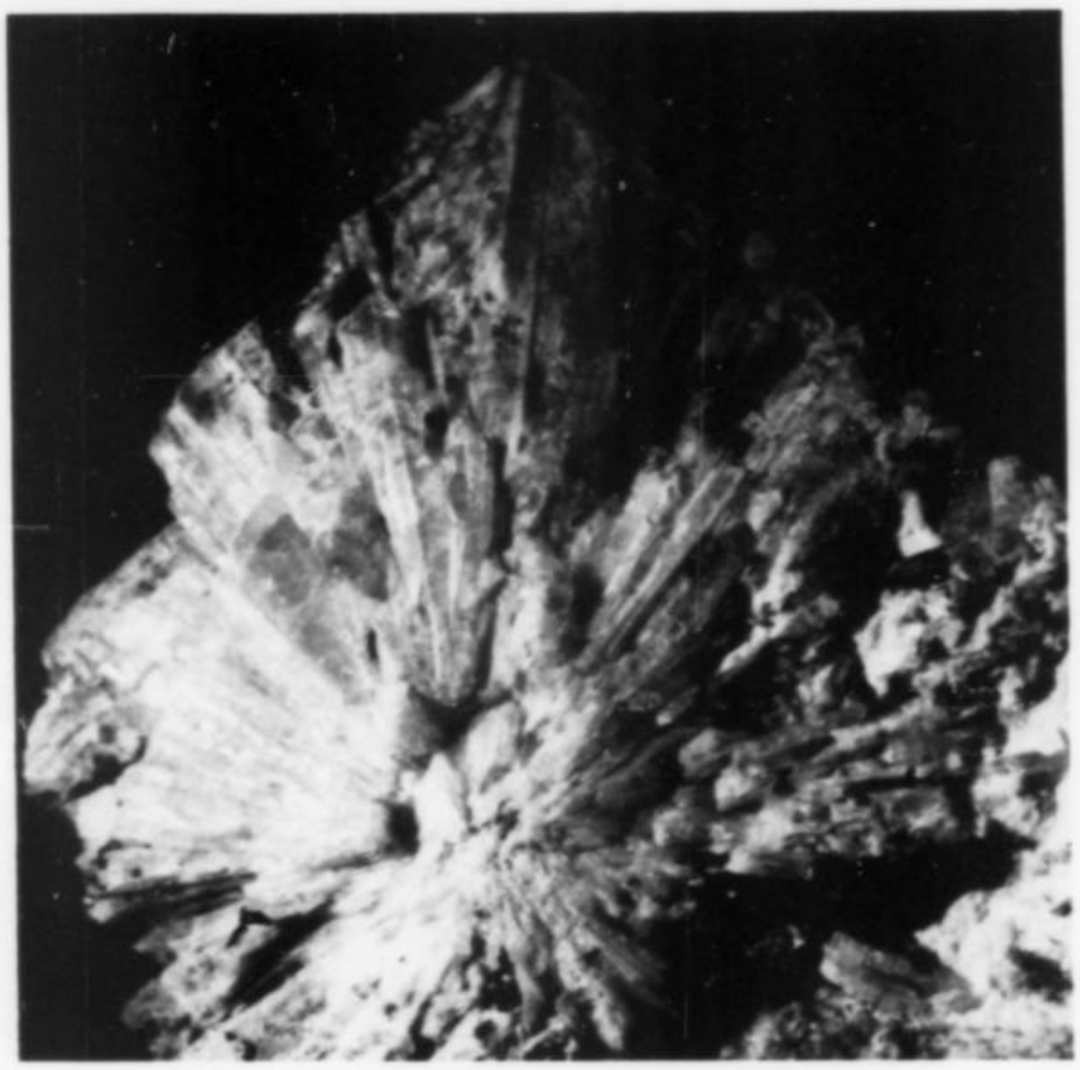

Figure 16. **Rosette of yellow titanite in natrolite. Field: 52 x 72 mm.**

Diopside $CaMgSi_2O_6$

Prisms of diopside in lengths up to 30 cm occur in several places in the alteration zone of the ultramafic rocks. They seldom show well-developed crystal faces.

Phlogopite $KMg_3Si_3AlO_{10}(F,OH)_2$

Phlogopite is the most common mineral in the alkali-metasomatically altered rocks, where it is associated with perovskite, magnetite, apatite, melanite or diopside. A remarkable phlogopite zone (glimmerite) is developed in the altered dunite not far from the inner contact of the melilitolite ring dike. The zone is nearly concentric, 6–8 m wide and can be traced over more than 1 km. In this zone as well as in other parts of the altered rocks phlogopite forms thick books and flakes up to 50 cm across.

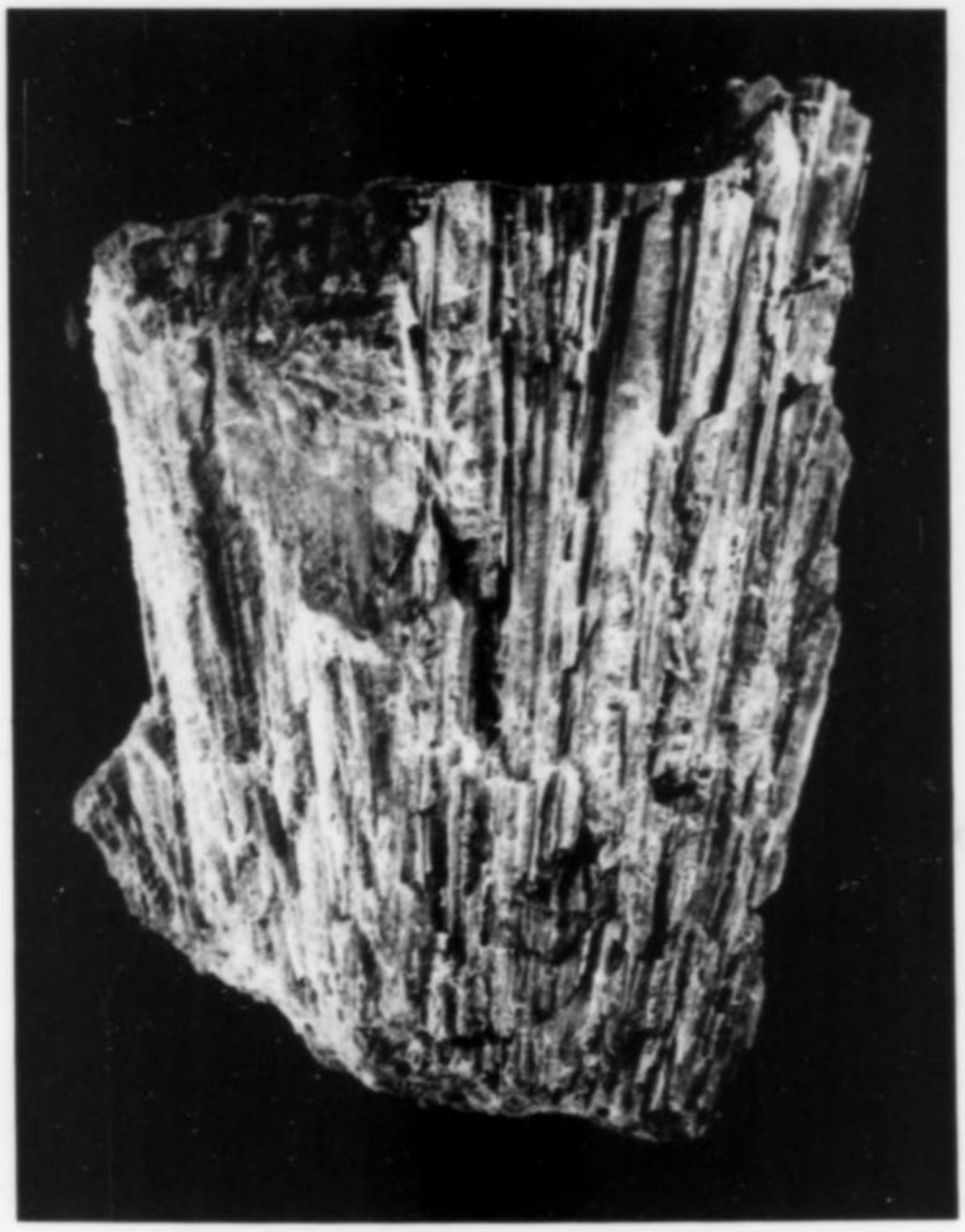

Figure 17. **Columnar aggregate of brown titanite. Field: 105 x 160 mm.**

Table 1. **Minerals identified from the Gardiner complex.**

Aegirine (some titaniferous)	Lorenzenite
Albite	Magnesio-arfvedsonite
Anatase	Magnesio-hastingsite
Andradite (var. melanite)	Magnetite
Antigorite	Melilite
Arfvedsonite	Microciine
Augite	Monticellite
Barite	Natrolite
Barytolamprophyllite	Nepheline
Biotite	Nosean or Hauyne
Calcite	Olivine
Cancrinite	Pargasite
Catapleiite	Pectolite
Cebollite	Perovskite
Chalcopyrite	Phlogopite
Chromite	Plagioclase
Clinochlore	Pyrite
Clinohumite (titaniferous)	Quartz
Diopside	Salite
Dolomite	Schorlomite
Eckermannite (?)	Sodalite
Eudialyte	Sphalerite
Hematite	Strontianite
Hydrogarnet	Tenorite
"Hydronephelite"	Titanite
Hydroxylapatite	Tremolite
Ilmenite	Vermiculite
Kaersutite	Vesuvianite
Katophorite	Vishnevite
Lamprophyllite	Xonotlite
Loparite	Zircon

Figure 18. **Lamprophyllite with black amphibole and natrolite. Field: 80 x 110 mm.**

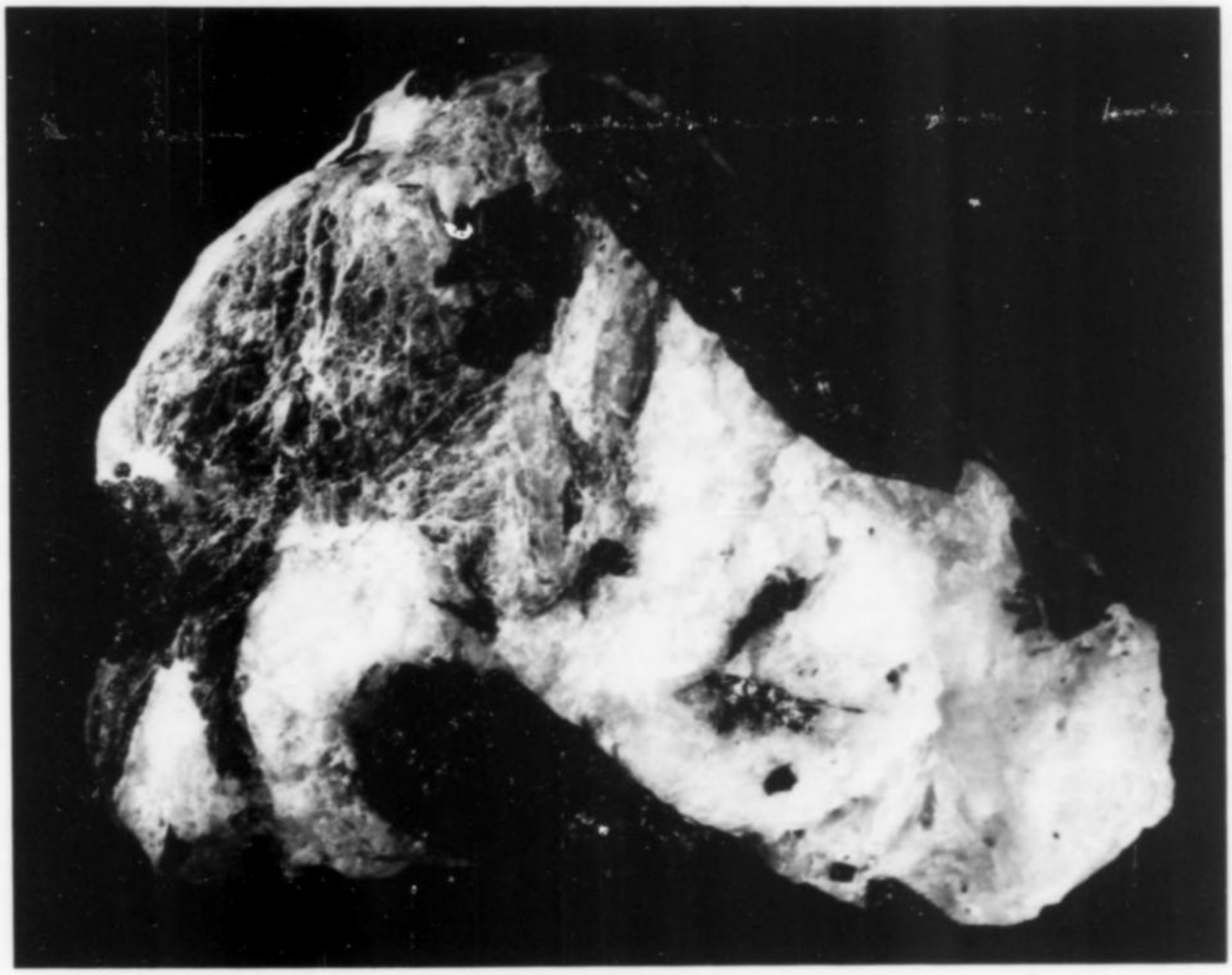

Figure 19. **Gemmy titanite in natrolite. Field: 25 x 33 mm.**

ACKNOWLEDGMENTS

Our field work was carried out with the financial support of the Danish Natural Science Research Council, to which we are most grateful. J. Bailey kindly corrected the English of the manuscript.

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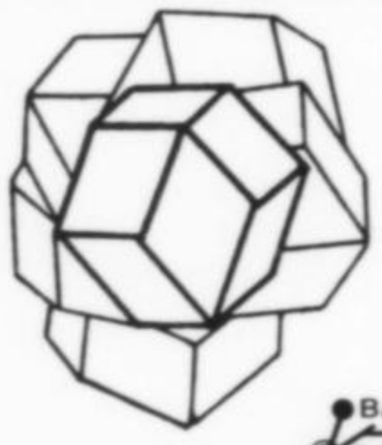

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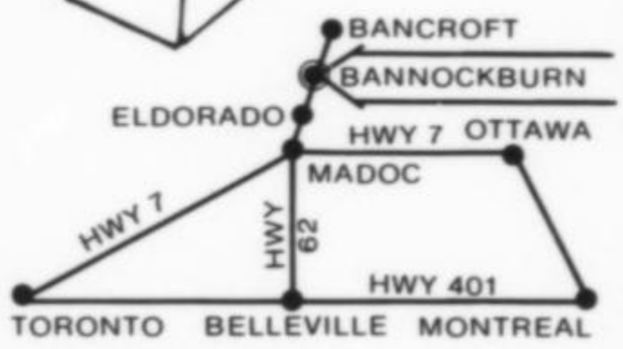

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NORTH CAROLINA KUTNOHORITE

During 1983 and 1984 a large amount of fine crystallized kutnohorite ($Ca(Mn,Mg,Fe^{+2})(CO_3)_2$) was collected from a working quarry near Moncure in Lee County, North Carolina. Several pockets exposed by blasting yielded approximately seven flats of high-quality specimens including matrix pieces and "floaters"; all specimens were found suspended in and protected by montmorillonite clay.

The kutnohorite (analyses by Florian Perini) occurs as intergrown groups of small (several mm) highly curved and lustrous crystals which are pink when freshly removed from the clay but which fade somewhat upon drying. Associations include crude crystals of manganocalcite, calcite, pyrite, pyrolustite (?) dendrites and an iron-rich kutnohorite. The largest pocket measured roughly 1 x 1 meter.

The quarry is currently inactive but is expected to reopen. Quarry operators have been very cooperative in allowing organized groups collecting access, but individual collectors are not admitted. In any case, collecting there will probably not be worthwhile again until blasting resumes.

Specimens are available from Edward Brazeau (*Mineralogical Studies*), who provided the above information and loaned a specimen for photography.

Hixon gem collection, and one of the largest native gold displays in the world.

In May the museum's new Deutsch Gallery ("Gemstones and their Origins") opened amid great fanfare. A spectacular Harry Winston display of gems, combined with an equally remarkable Smithsonian exhibit, dazzled the black-tie attendees on opening night. The fabulous 127-carat Portuguese diamond, the 182-carat Star of Bombay sapphire (once owned by Mary Pickford) and Marie Antoinette's diamond earrings were all included in the Smithsonian exhibit.

The museum recently announced the formation of a new Gem and Mineral Council to promote "the exchange and dissemination of knowledge and information concerning gems and minerals, and [to provide] supplemental funding for exhibition, acquisition and research programs of the museum's mineralogy section," under curator Anthony Kampf. Membership is open to all interested individuals; annual dues are $100. Bimonthly council activities are planned to include field trips, lectures, seminars, and visits to foreign mineral museums.

For more information call (213) 744-3438.

BUTTE HURLBUTITE

Chris van Laer (620 N. Alaska, Butte, MT 59701) has recently reported finding six crystals of the very rare mineral hurlbutite ($CaBe_2(PO_4)_2$) at a small pegmatite exposure east of Butte. The crystals are pseudocubic in habit and measure up to a remarkable 2.5 cm on an edge. The prism faces are etched, and the color ranges from pale yellow to greenish yellow. Hurlbutite was first found at the Smith mine near Newport, New Hampshire, and small amounts have also been identified from Sweden, Madagascar and Brazil (*Mineral News,* July 25).

RED CLOUD WULFENITE

The big news from Arizona in recent times has come from the old and famous Red Cloud mine north of Yuma in Yuma County. A renewed attempt at commercial mining in the last few years

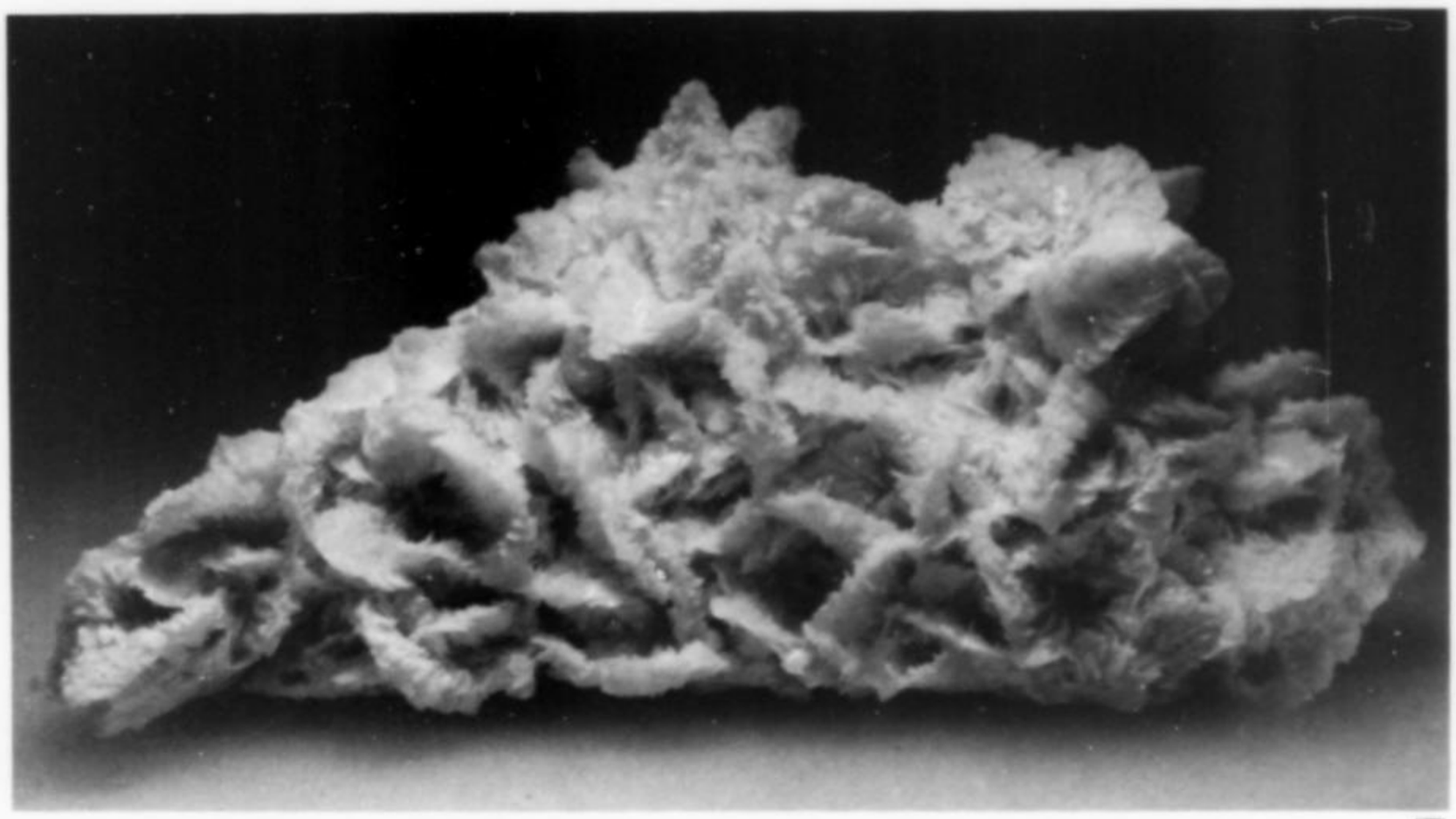
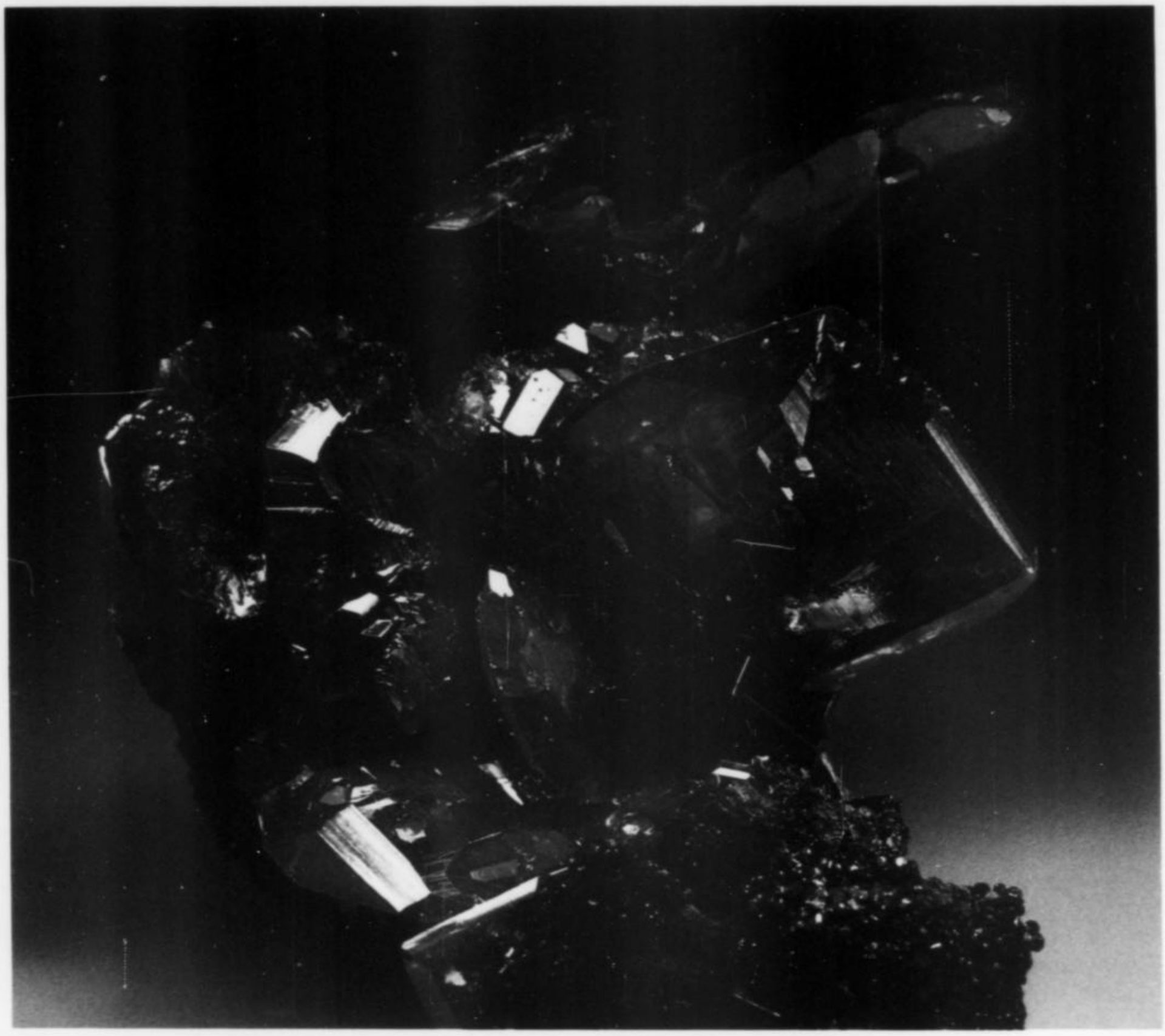


Figure 1. **Cream-colored to pale pink kutnohorite in curved crystal aggregates, from Moncure, Lee County, North Carolina. The specimen is 10.5 cm across.**

NEWS FROM THE L.A.C.M.

The Natural History Museum of Los Angeles County houses what is probably the most important collection of Gems and Minerals in the western United States. Over 32,000 specimens are preserved there including the Mark C. Bandy collection, the F. C.

failed, but clearing of a number of old back-filled stopes gave access to fresh sections of the south stope above the 270 level. Collectors have been working intensively, often in alternating shifts, and finally broke into an important pocket. Bruce Barlow and Bob Lane were the lucky ones on duty at the time of the discovery.



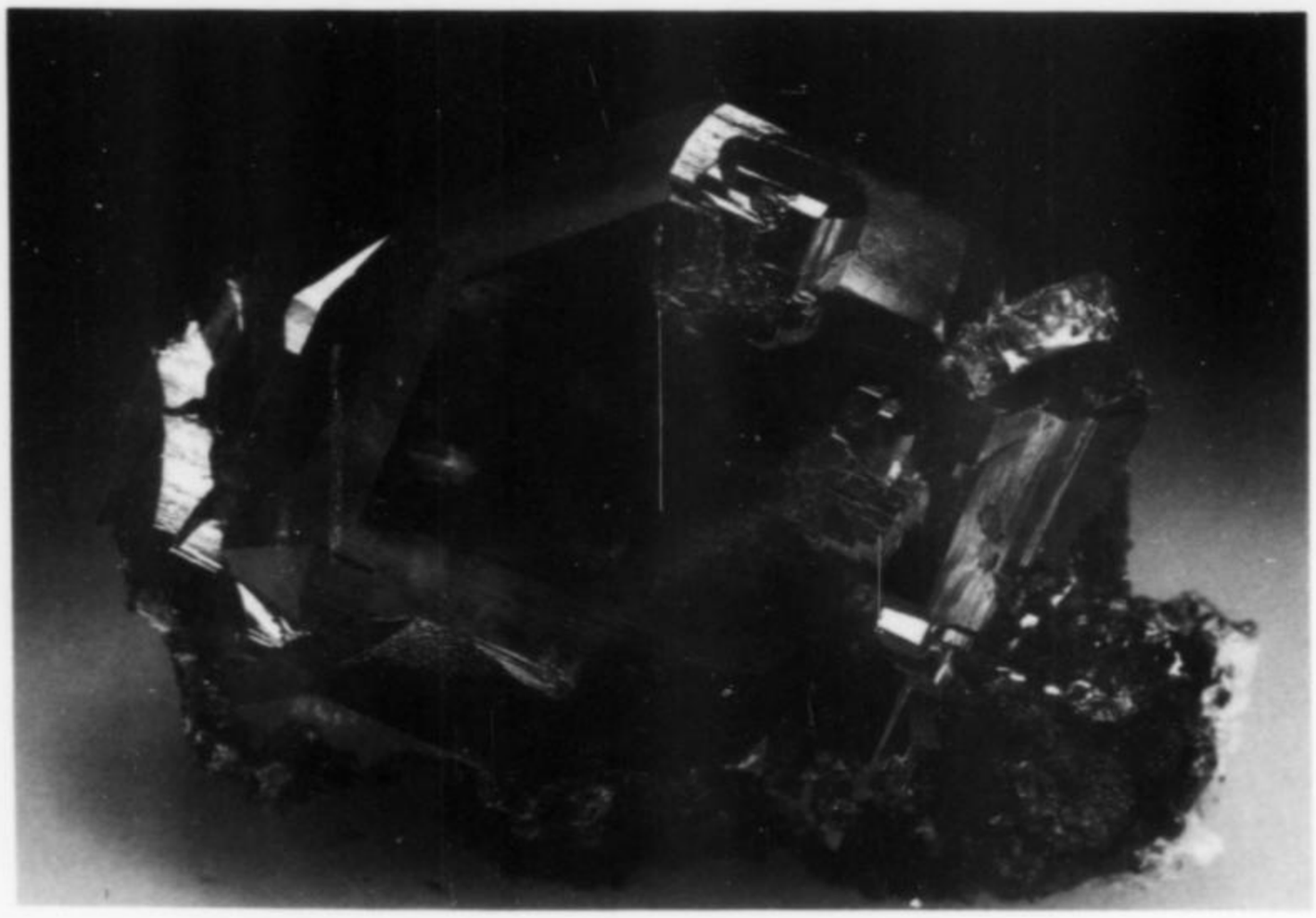


Figure 2. (above) **The finest specimen from the recent Red Cloud mine strike. The largest crystal (upper right) measures 4 cm. Bob Lane collection.**

Figure 3. **A fine single crystal of Red Cloud wulfenite from the recent find. It measures 3 cm (too large for a thumbnail). Bruce Barlow collection.**

According to Barlow and Lane, the pocket measures about a meter wide, 60 cm tall and perhaps 30 cm deep. They intersected it at the bottom and could not get into a position to see inside; but, by reaching in they could feel that it was filled with blackish powdery or muddy oxides in which were suspended wulfenite crystals. The pocket was slowly emptied from that awkward position, yielding approximately 300 thumbnail-size crystals, 15 high-quality miniatures and one fine cabinet specimen. The pulverulent material had apparently helped to protect the crystals from damage, and most were recovered in good condition.

The best specimens have bright orange-red crystals 3 to 4 cm in size, sometimes in attractive groups. There was a lot of talk when

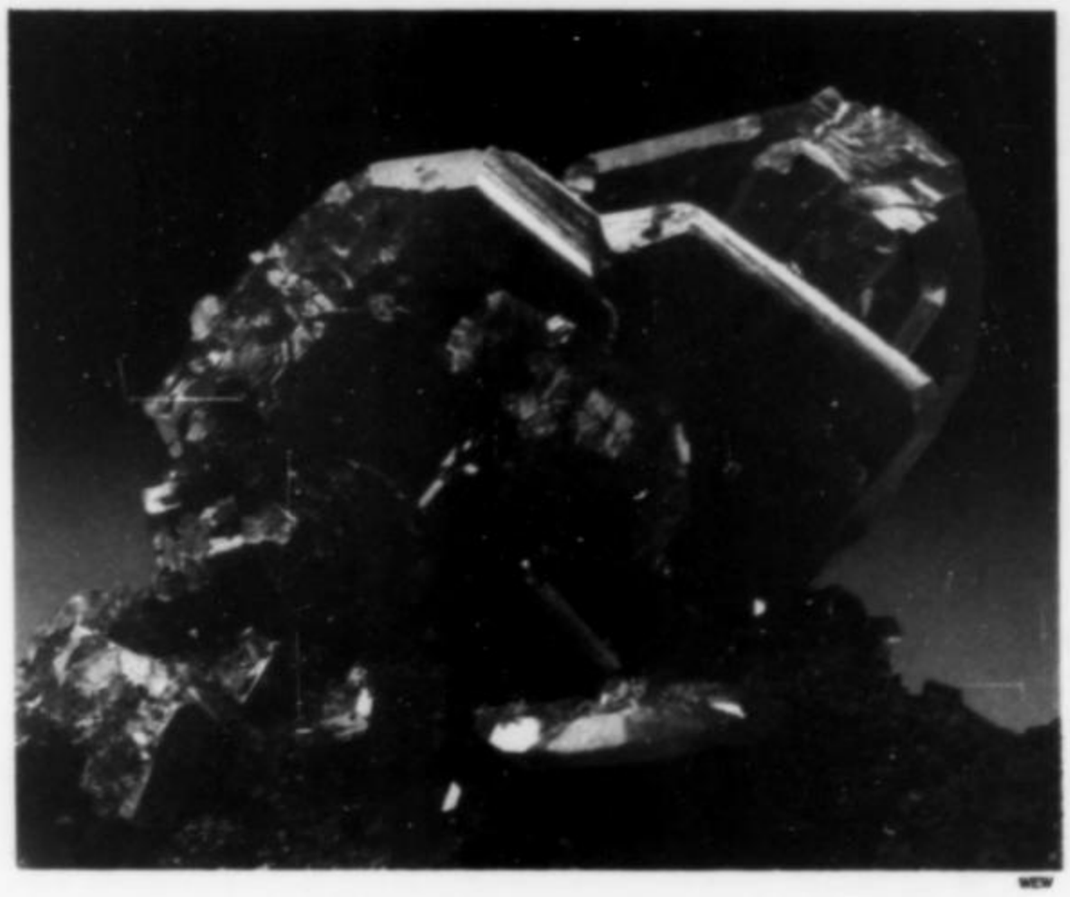


Figure 4. **Another Red Cloud wulfenite from the recent find. The crystal measures 3.1 cm. Bruce Barlow collection.**

these were found suggesting that they are equal to or better than the famous Ed Over specimens found in 1938. Actually very few people have ever had the great privilege of *handling* the various Ed Over crystals; overenthusiastic comparisons are therefore understandable. But the newly found crystals are superb indeed, and quite a pleasant surprise from a locality that has continued to yield fine specimens of the world's most sought after wulfenite for over a hundred years.

The pocket also produced some very interesting skeletal-stalactitic goethite heavily sprinkled with bright red mimetite crystals to 1 or 2 mm each. (See G. M. Edson's article on the Red Cloud mine in vol. 11 (1980), no. 3, p. 141–152.)

PAKISTAN EPIDOTE

Some exceptional and distinctive epidote crystals have come out of northern Pakistan recently. The crystals are up to 9 cm tall, very lustrous and *gemmy,* with fine greenish brown color. Single crystals only have reached the market thus far, but the quality is superb and the habit sufficiently idiosyncratic to warrent a place for these crystals alongside the best from other localities worldwide. Unfortunately little is known about the precise locality except to say that it is not a pegmatite and is therefore not one of the localities already well-known for gem minerals. At least a few flats of these epidote specimens have appeared, most specimens being in the thumbnail to small miniature size range.

HOUSTON SHOW 1985

Our correspondent Art Smith in Houston provided the following report on the recent Houston Show:

> The Houston Gem and Mineral Show was held the fourth weekend in August this year, somewhat earlier than has been traditional in the past. There were two major museum exhibits: the Houston Museum of Natural Science displayed a selection of pieces from the Sams collection, and Harvard displayed fine Tsumeb specimens.
>
> Mineral dealers at the show were well stocked, and a few new things showed up.
>
> • *Roberts Minerals* and Chris Wright had chlorite phantoms in single quartz crystals up to 12 cm, from Buenopolis, Minas Gerais, Brazil.

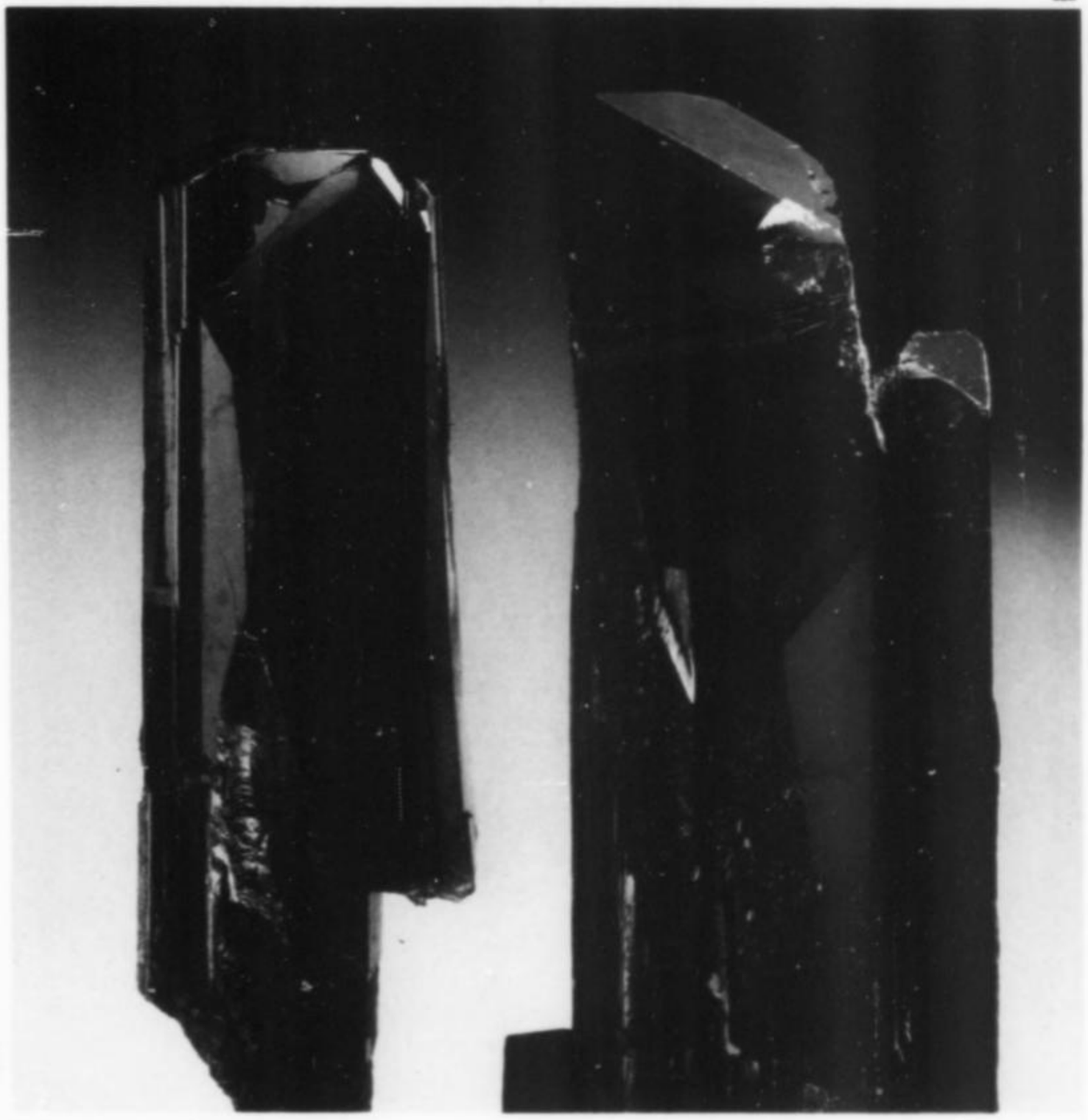


Figure 5. **Epidote crystals from Pakistan. Width: 2.3 and 2.5 cm. Western Minerals specimens.**

• Chris Wright and *the Rocksmiths* obtained some unusual, though not particularly showy, twinned monazite crystals to 2 cm, also from Minas Gerais.

• Alain Carion had specimens of fibrous blue halite from Mulhouse, France. The material consists of large (to about 10 cm) fragments of a cross-vein filling.

• *Collector's Choice* and Chris Wright provided a nice selection of creedite from Santa Eulalia, as they did at the last Tucson Show. Some of the more recent material is darker in color, associated with transparent gypsum crystals. However, the creedite crystals are rather small, generally under 1 cm.

• *Collector's Choice* also had a newly arrived flat of lustrous acanthite and polybasite crystals which proved to be the hit of the show. Most crystals are around 1 cm in size, though one parallel-growth crystal measures 6 cm. These came from Guanajuato, Mexico.

• Keith Williams offered a nice lot of "iron cross" pyrite twins up to 2 cm in size, from the Wyoming mine near Red Cliff, Eagle County, Colorado.

• *Mineral Kingdom* had some large (1 x 2 cm!) individual crystals of cuprian adamite ("cuproadamite") from Tsumeb, Namibia.

• New from Pakistan were some gemmy, amber-colored spessartine crystals to 2 cm, with muscovite and albite. There were also a few 3-cm epidote crystals available (see above). Dave Wilber, *Roberts Minerals* and other dealers had these.

• *Kristalle* offered, as usual, a nice selection of California gold, but the gold specimen from the Dixie mine, Clear Creek County, Colorado, had all the local Colorado collectors buzzing. The specimen measures about 7.5 x 10 cm and carries a dense growth of leaf gold, with the leaves all stacked on edge like pages in a book.

W.E.W.

Letters

NEVADA ISSUE

We would like to compliment you on the hard work which obviously went into the recent Nevada Issue (vol. 16, no. 1), and on the fine end-product which, as usual, resulted. We all owe the various authors a sincere "thank you."

We also think it would be appropriate to recognize Fred and Dorothy Barnes of the Getchell mine. Fred and Dorothy have been friends to countless visitors at the mine, providing much-needed water, food, digging information, shelter, physical assistance, and more than one cold beer on a hot July afternoon. Without their 30 years of generosity and unselfish help, a great many fine specimens and rare species from Getchell would never have been preserved.

Forrest & Barbara Cureton
Tucson, Arizona

In one word: FANTASTIC! (The Nevada Issue) Thanks for everything.

Matthew Walker
Crescent City, California

FAN MAIL

I received the enclosed notice that my subscription to the *Mineralogical Record* will expire with the next issue. Since I thoroughly enjoy this magazine, have a complete run at the present time, and want to continue receiving it, I am thus opting to become a "Life Member." I enclose my check for the Lifetime Subscription, so I shall never again have to worry about my subscription expiring!

Now that I have acquired a complete set, the Index covering the first 14 years becomes even more important. Thus, my payment also includes $20 for a postpaid shipment of this Index. Since I use the *Mineralogical Record* almost daily at present, I would appreciate your expediting this item to me.

I don't know if a Lifetime Membership holds any special privileges, but knowing I will always receive the top periodical in the minerals field is probably privilege enough! Best wishes for the continued success of the *Mineralogical Record.*

Prof. Marvin D. Rausch
University of Massachusetts, Amherst

My father has requested a subscription to the *Mineralogical Record* for Father's Day this year; check enclosed. He is eagerly awaiting his own issues, having been very much impressed with the back issues we showed him!

Thank you for your assistance and for the beautiful work you produce. Everyone we've shown the *Mineralogical Record* to has agreed that it is the most beautifully done publication they've ever seen! It is certainly a source of enjoyment in our home.

Foster & Debbie Hallman
Reno, Nevada

LATE RENEWAL

I apologize (for this late renewal). Somehow the bill slipped into the Precambrian era on my desk. Because I'll be away for a few weeks I decided to first take a field trip to my desk, and this bill came up in a drill core.

Marilyn F. Dodge
Providence, Rhode Island

Thank you for the payment on your 1973 renewal invoice. Please keep drilling. (Just kidding!)

Ed.

PLASTIC MAILERS

Since you started using the new clear plastic mailing envelopes for the *Mineralogical Record,* my copies have arrived badly folded. The *Record* is too magnificent to get such bad treatment!

L. J. F. Horvath
Oudehorne, Netherlands

Our change to plastic mailers was carefully considered. Actually, less than ten copies per issue, of about 6000 total, have been damaged in the mail since the switch. At least that's how many requests we've had for replacements. Although the plastic is slightly less resistant to folding, it is much more difficult for the post office to tear, and it is waterproof. Arizona Highways *magazine just made the same change and obtained the same superior results, as did* American Mineralogist. *You might try complaining to your postman.*

Ed.

MORE ON UNITS

Enough (sufficient)! Articles (papers) in your magazine (journal) would (should) read (peruse) better (easier) without (lacking) measurements (amounts) in both (two) units (systems).

Why not just remind your readers of the common conversion factors once in a while and let it go at that?

Henry C. Caldwell
Philadelphia, PA

Actually, since our conversion to metric as the predominant system, we have tried to limit the use of parenthetical English equivalents but there are a number of cases where we feel they are useful. One reader, for example, wrote to complain that, whereas mileage notations to localities in the Mineralogical Record *are now supplied in kilometers, the odometers on American cars still register only in miles and an inconvenient conversion in the field becomes necessary. Also, some measurements given should rightly impress the reader with their magnitude (measurements of very large crystals, for instance), and we wouldn't want the effect to be lost on the many readers who don't get an instantaneous mental vision of how long 11.3 cm is. Then there are problems relating to altitude measurements, which are given only in feet on American topographic maps, and common mining usage of parameters such as ounces-per-ton. And so on. Life is compromise; we try to be reasonably flexible for maximum clarity.*

Ed.

ERRATA

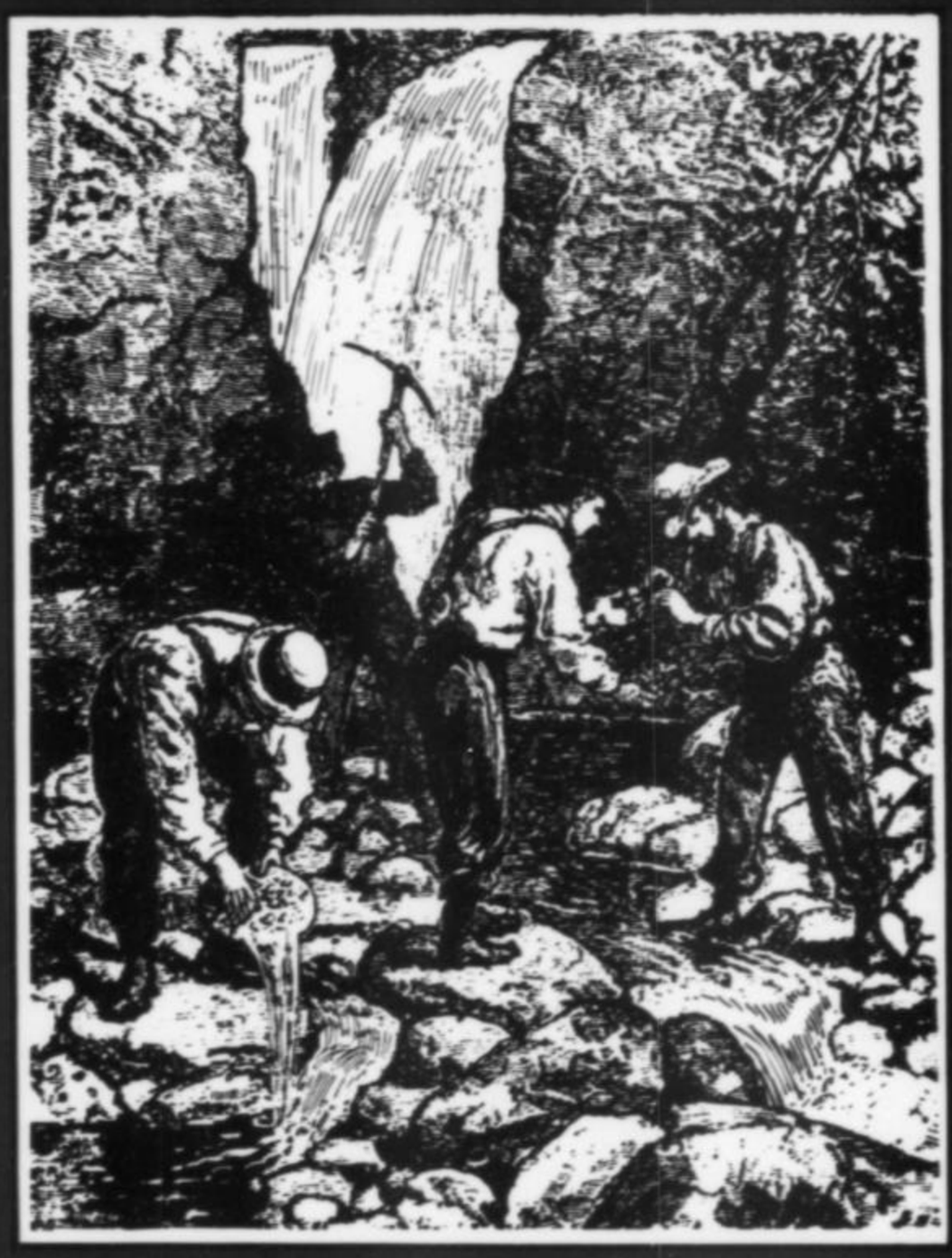
Two figures were purposely cut from Bill Henderson's article in the March-April issue on *Microminerals of the western volcanics.* This was simply due to a lack of space, but reference to these two figures (24 and 25) was left in the text inadvertently, perhaps causing readers some confusion. Since everyone is now clamoring to see the mystery photo of Mike Groben and Al McGuinness, I'll run it here as soon as space permits.

In Cynthia Marcusson's article on the Himalaya mine in the Tourmaline Issue (vol. 16, no. 5), the Figure 4 caption actually applies to Figure 5, and the caption for Figure 4 should read: "Stilbite crystals to 4.2 cm, perched on a tourmaline crystal 3.5 cm across. William Larson collection." Our apologies for these errors.

Ed.

California Mi

Northern



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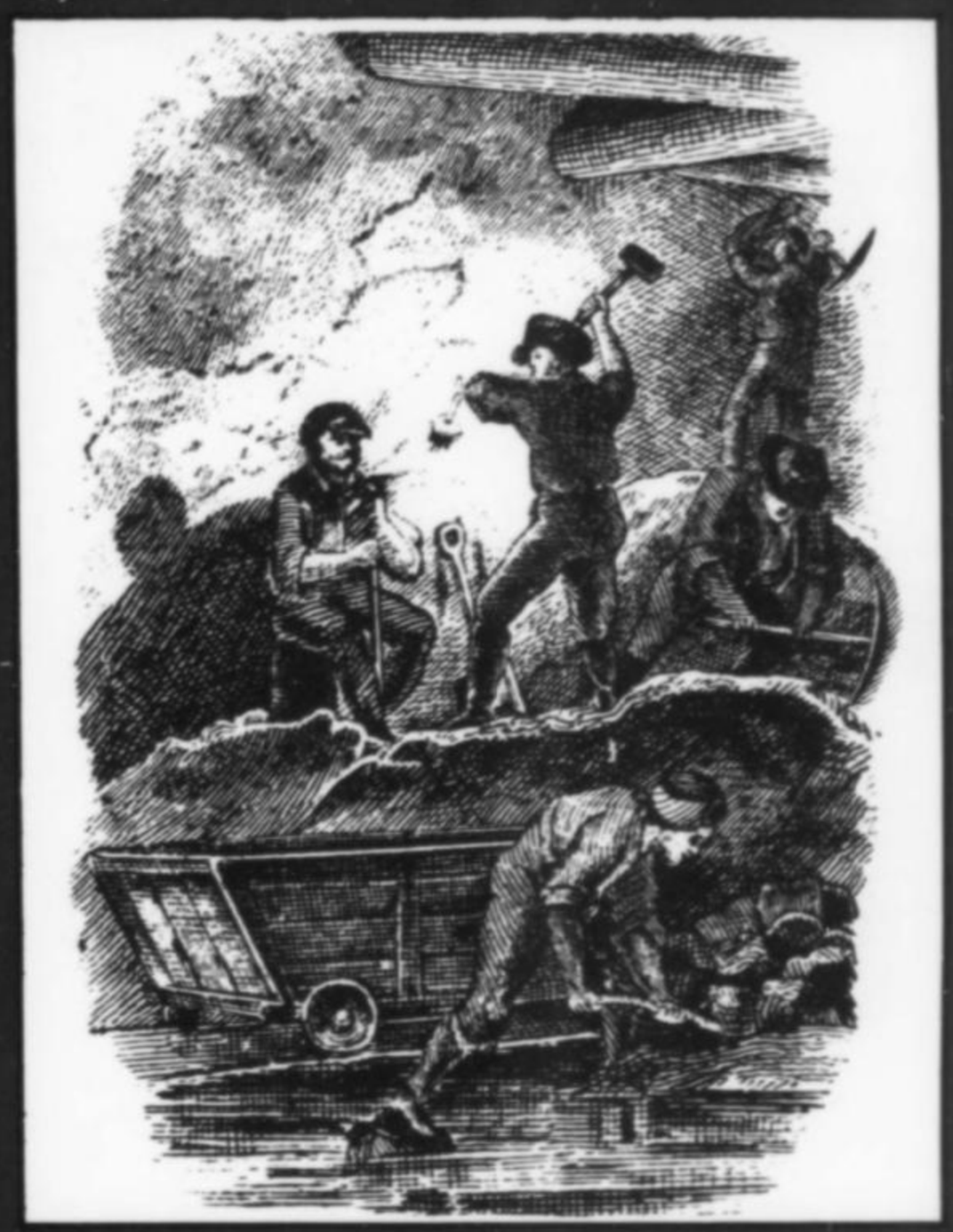

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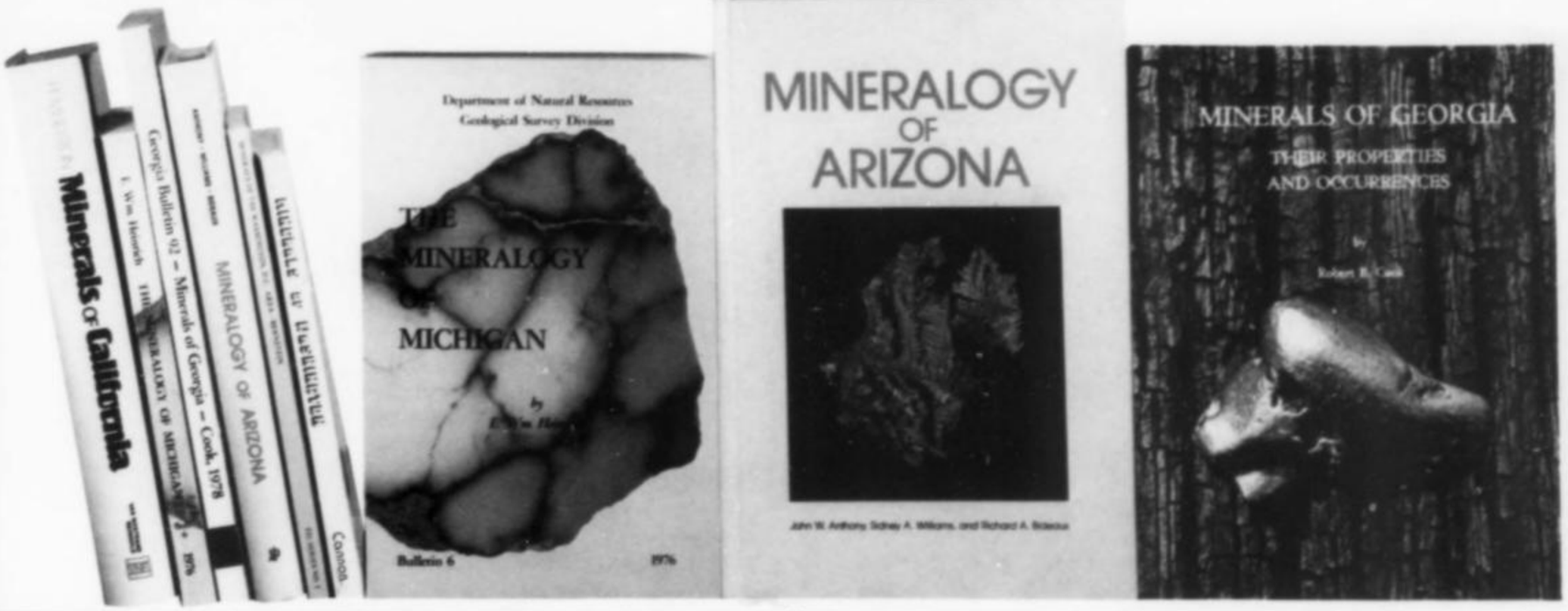

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